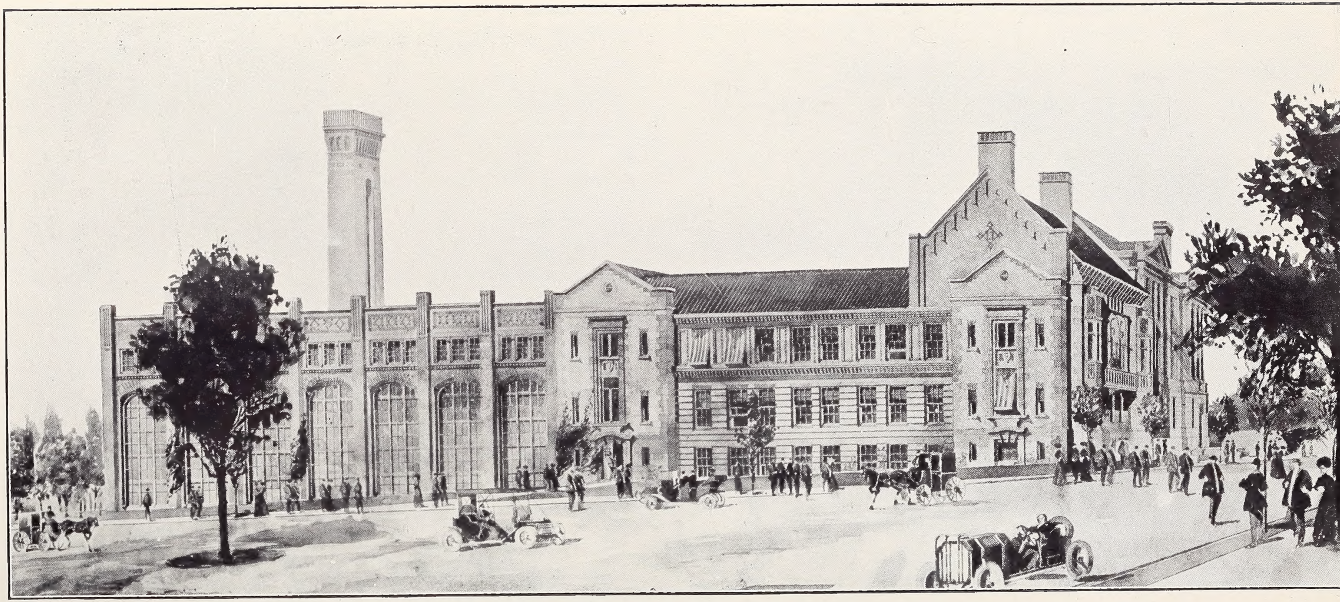

Steam, Gas and Hydraulic Laboratory Building of the University of Toronto — Darling & Pearson, Architects

This shows the building as it will appear when completed. At present the whole laboratory part is completed which comprises all of the building to the left of, and including, the first window to the right of those protected by awnings.

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THE NEW LABORATORIES OF THE UNIVERSITY OF TORONTO, FOR STEAM, GAS AND HYDRAULIC WORK.

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The first engineering laboratory in Toronto was formally opened on February 24th, 1892, in the School of Practical Science which is now the Engineering Building of the Faculty of Applied Science and Engineering of the University of Toronto. This laboratory consisted of three departments: First, the department for testing materials of construction. Second, the department for investigating the principles governing the application of power, which department included the steam laboratory, the hydraulic laboratory and the electrical laboratory. The third department was an astronomical and geodetic laboratory.

In the steam power department there were two boilers, the larger of 50 H.P. capacity, a 50 H.P. Brown engine with condensers and pumps, and a machine for measuring journal friction and for testing lubricants.

The hydraulic division contained a three-throw pump driven from the Brown engine, a large impulse wheel, and two large tanks for orifice and weir experiments.

This equipment served very well at the beginning; there were not many students and thus a large number of pieces of apparatus was not necessary, and the apparatus actually installed was so well selected and suited the purpose so well that much valuable instruction was given on the machines mentioned.

As the work expanded and the number of students increased small additions were made, but up to the time the writer was appointed demonstrator in this work in 1898 the only additions were two reaction turbines, neither of which was set up for operation, and a crude type of centrifugal pump, together with tanks for calibrating the orifices and weirs already mentioned.

During the past decade great advances have been made in the development of power, more especially in Canada, where we have been appreciating to some extent the value of our water-

powers. The gas engine has also been brought to a high state of perfection and suction gas has presented such great possibilities as to make it an important source of power.

Further, the work of the Engineering Faculty has been recognized by the people of the province in such a way that the attendance has increased by leaps and bounds.

For these and other reasons it has been necessary to increase steadily the equipment of the power department to illustrate the modern methods and also to provide sufficient apparatus for the increased number of students.

As the number of pieces of apparatus increased the available space became more and more crowded until during the last few years it has been difficult to carry on the work successfully. The steam laboratory had been placed in a comparatively low basement and the moisture and heat produced by the steam made the working conditions very bad.

After careful examination of the whole question, the Board of Governors of the University decided in June 1908 upon the erection of a new building to accommodate the laboratories for steam, gas and hydraulic work and also for all general mechanical engineering, and the building described in this article is the result.

The money appropriated for the building as erected was between $85,000 and $90,000 and for new equipment approximately $22,000, although most of the apparatus which had been installed in the old laboratory has been moved in, so that the total value of the apparatus and equipment in the new building would considerably exceed the $22,000 mentioned above.

New Laboratory.

The building about to be described contains the laboratory for steam and gas engines, steam boilers, refrigerating machinery, belt and oil testing, and other similar work, and also that for hydraulic work of various kinds. It is built of white brick with white stone trimmings and consists of two parts divided by a wall running east and west, the part to the south of this wall having but one floor while the part to the north has three floors.

When the building was first under consideration a number of very difficult problems presented themselves, partly in the way of finding sufficient room in already overcrowded grounds, and partly in the way of making the building harmonize with the other University buildings. In order to carry on the instruction required a boiler room was necessary which had to be placed on the outside of the building in order to facilitate the delivery of coal and the removal of ashes. Then, too there was the problem of stacks, two of which have been provided for experimental purposes, and the necessity of good light and large rooms, so that it was difficult to make the building look attractive.

The architects considered the question with great care and

arranged a scheme by which the boiler room and other unattractive parts will be eventually hidden when the entire group of buildings for the Faculty of Applied Science is completed.

The first figure shows the building as it will finally appear. The front will be to the west and it will face on the main University road which runs north from College Street, directly opposite University College. To the north of the building it is proposed in future to run a cross road east from the one above mentioned, the new road separating the Mechanical Laboratories and the building which will in time replace the present Engineering Building. At present there is only a very narrow passage between the two buildings. On the south the building will be connected to the future extensions to the Chemistry and Mining Building, which extensions are to be so planned that almost the entire south side together with the boiler room, which is now exposed, will be hidden.

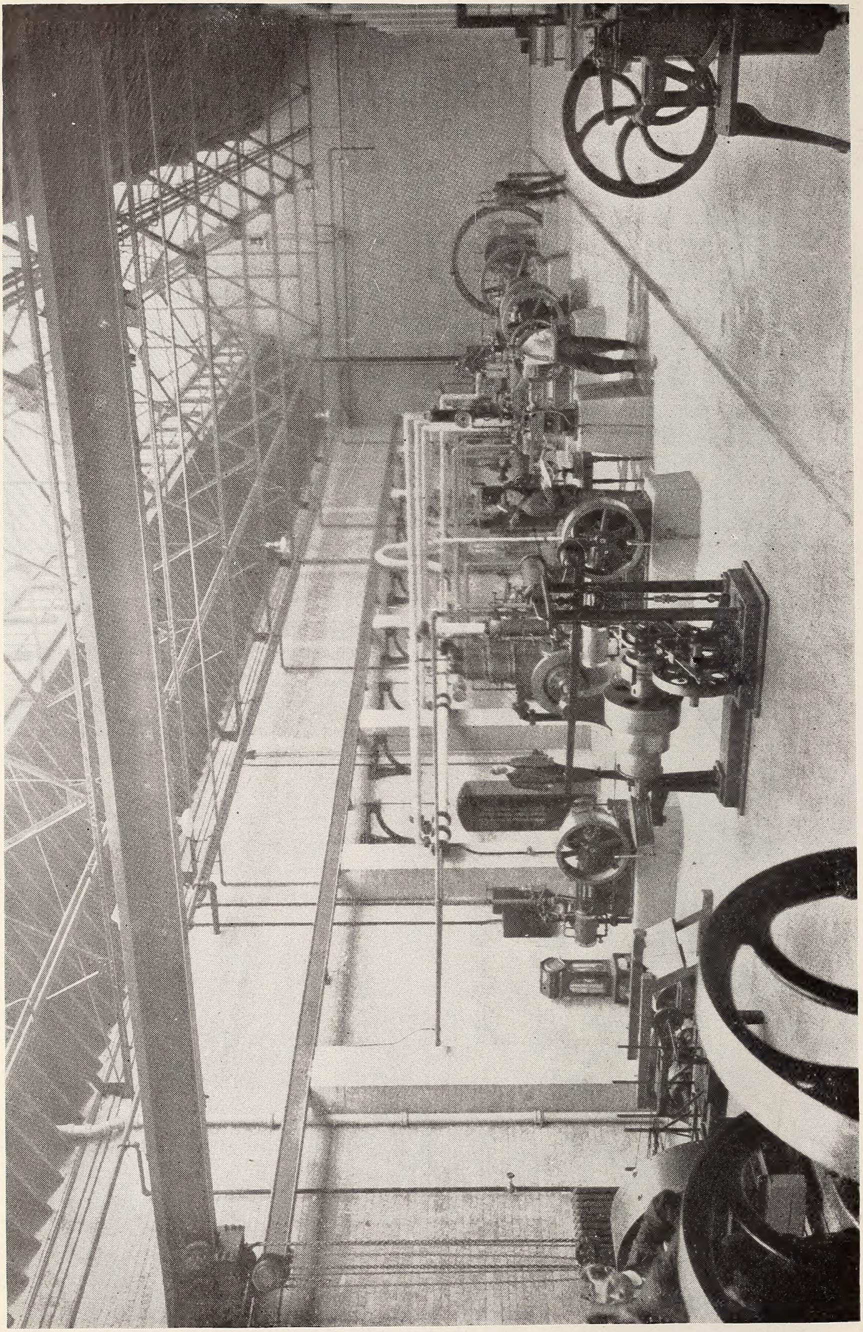
The buildings will thus have a fine appearance and will with the Chemistry and Mining Building form a fine, large block quite in keeping with the nature of the work being done by this Faculty of the University.

Owing to the other pressing needs it was felt by the Board of Governors that it would be impossible to erect the entire building at the present time and as laboratory accommodation had to be provided the part containing this was erected and a reasonable number of class rooms provided in it, while the front part, which will contain more rooms of this nature, has had to be omitted for the present.

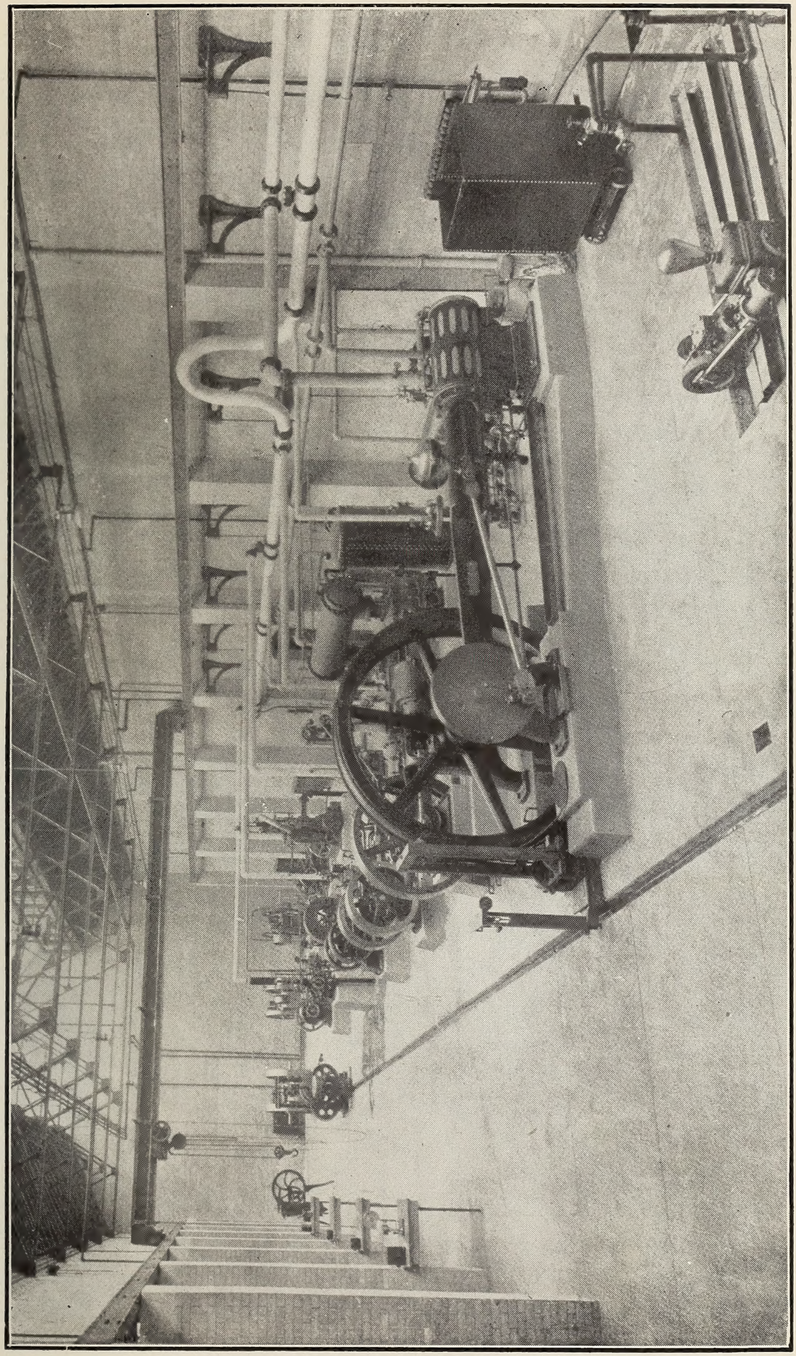
The Thermodynamic Laboratory.

Beginning with the space devoted to the heat engines and general mechanical work, we enter the Thermodynamic Laboratory. This laboratory occupies with the boiler room, the whole south half of the building and exclusive of the latter is 156 ft. long by 60 ft. wide with roof light throughout, there being no windows in any of the walls. It is divided into two parts, one being 40 ft. wide and the other 20 ft. wide, running the entire length of the room. The wider part has a clear height of 23 feet at the sides, being considerably higher in the centre. The narrower part has a clear height of 12 feet, and is divided up into smaller parts, there being eight small rooms, to be described later, and a space for delivery and unpacking of goods. The light is obtained from the roof and is as near perfect as can be expected. The ventilation is also very good, being obtained by opening windows in the roof, a method which works so well that the building can be kept quite cool even with all the machines operating at once.

Internal Combustion Engines. — The equipment in the two parts of this laboratory may now be described in some detail, beginning with that in the larger part. The west end of this



Thermodynamic Laboratory—General View from West End



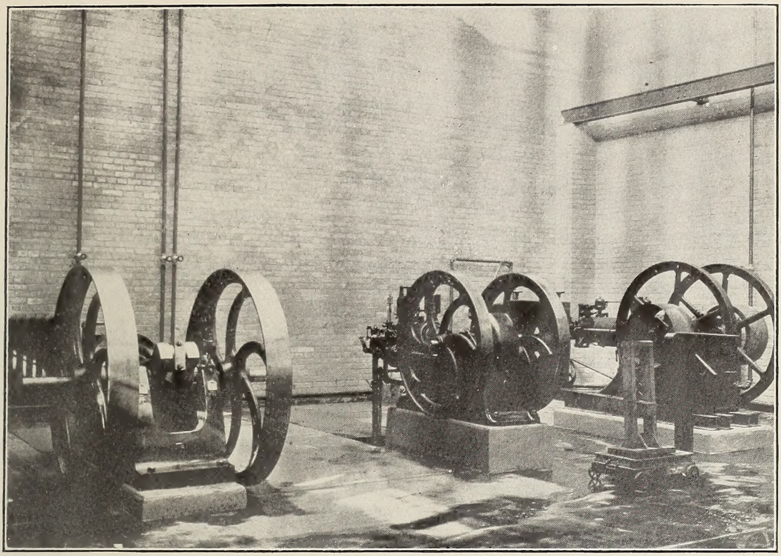
Thermodynamic Laboratory—General View from East End

has been devoted to gas, oil, and other internal combustion engines and the equipment consists of a 10 H.P. engine built by Fielding & Platt, of Gloucester, England. This engine has a cylinder 7 in. diameter and 14 in. stroke and has been specially built for experimental work. It is designed for variable compression, so that it may be adapted for use with different classes of fuels; and it is further equipped with three types of igniting gear, viz.: hot tube, high tension electric and a magneto gear, an arrangement being made so that the point of ignition may be varied at will while the machine is running. There is also a convenient method of varying the speed, and the use of heavy fly-wheels prevents great speed fluctuations at different speeds and loads. The engine is also fitted with vaporizing apparatus so that it may be run with oil, and has properly designed valves for the use of suction gas.

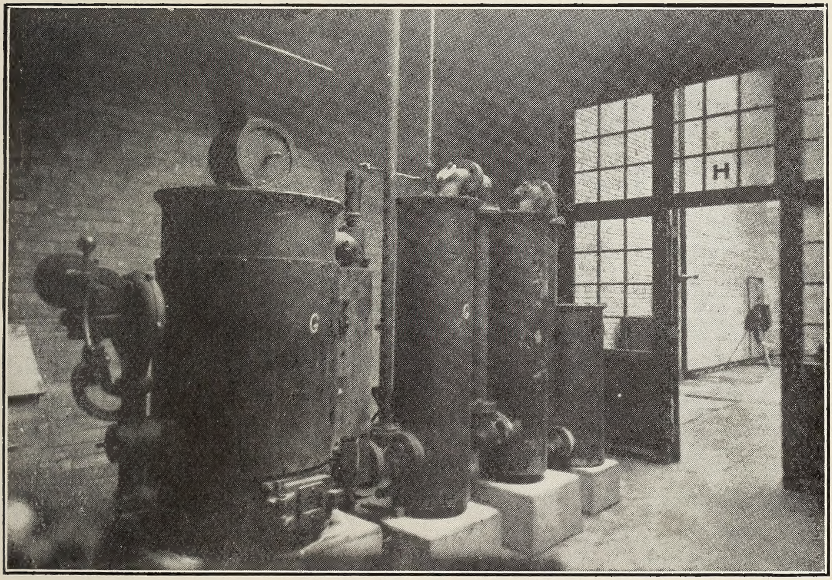
Adjacent to this engine is a larger one built by the National Gas Engine Co., Ashton-under-Lyne, England, and delivered in the building last June. It has a cylinder diameter of 9 in. and runs at a normal speed of 200 revolutions per minute, giving 22 H.P. on city gas. This machine is a very fine sample of a gas engine, being exceptionally heavy and having two massive fly-wheels which give steady speed. It has variable compression as in the case of the Fielding & Platt engine, and is designed for the use of either city or suction gas. It has only the magneto form of igniter, but the point of ignition may be altered without stopping the engine, which is noiseless in operation.

As already explained, both the above engines may be operated by city or suction producer gas. In the former case the gas is drawn directly through a meter where it is measured. When suction gas is used the latter is drawn from a producer in the small room in the south-west corner of the building. This producer, which was built by the Canada Foundry Co. of Toronto, consists of a generator complete with vaporizer, two scrubbers, and an expansion box from which the gas is delivered to a pipe conveying it directly to the engine. It is arranged so that fuel consumption tests may be made with it and the action of the producer carefully and accurately studied.

Adjacent to the Fielding & Platt engine and on the north side of it a test floor has been arranged so that engines of fairly large size may be conveniently tested, and it is hoped that various firms will, from time to time, place some of their engines at the disposal of the laboratory for examination and research work, as it is believed that this will prove of mutual benefit to the manufacturer and the University. This test floor is at present occupied by one of the earliest types of gas engines built by the Otto Gas Engine Co., Philadelphia. The engine has given good service in the engineering building for nearly twenty years and is retained to give some idea of the development of the gas engine of late years and because of its historical interest. It is



Thermodynamic Laboratory—The Gas Engines



Thermodynamic Laboratory—Suction Gas Producer

one of the slide valve type of engines with the old form of gas flame igniter, and is in good condition for test and comparison with the newer machines.

The space immediately in front of the engines just mentioned is used for two smaller test floors for gasoline and other similar small engines. Each floor is three feet square and has adjustable slots by which any small engine may be accommodated.

A marine gasoline engine with a cylinder 6 in. diameter and 6 in. stroke has been given by the Canadian Fairbanks Co., Toronto, at a nominal price and has been placed on one of the test floors mentioned and set up for experiments. This engine is to be equipped with an optical indicator made by Dobbie, McInnes & Co., Glasgow, so that its action may be accurately studied.

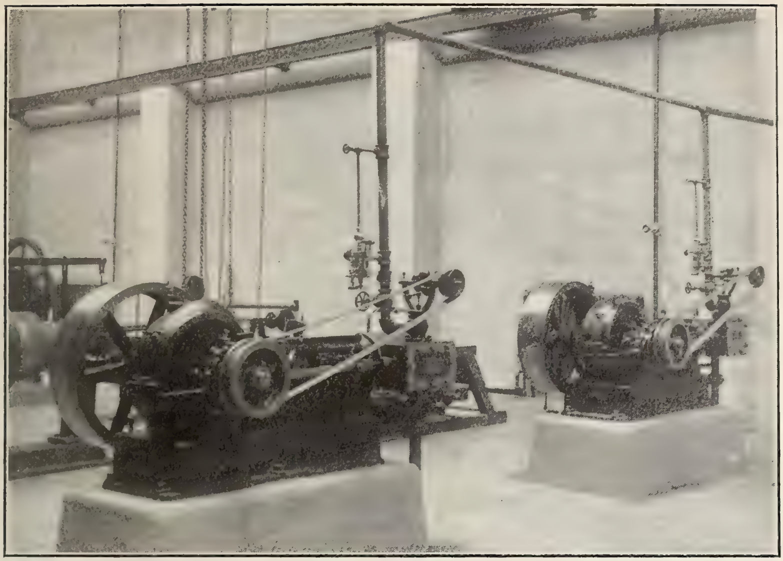
On the south side of the large room is an Ericsson air engine which serves to illustrate the action of this type of engine and to give figures on its economy. It is arranged to be run by city gas and a brake has been arranged to measure the brake horsepower at the same time as the indicator diagrams are taken. The efficiency of the machine as a pumping engine may also be found by allowing it to lift a measured quantity of water against a measured head.

Other Apparatus. — Proceeding farther east along the large room there is seen a fan on which experiments on its efficiency are to be made.

A little farther down is a slide valve model. This model is very complete and has been constructed so as to give results on almost any design of simple slide valve or link motion. The length of connecting rod is adjustable, as well as the angle of advance and throw of all eccentrics, the length of eccentric rods, radius and point of support and suspension of the link, etc.

There is also a journal oil tester built by Riehle Bros. of Philadelphia and having various adjustments. The journal used in the machine is a full sized railway car journal, and the design is such that the actual pressures and speeds occurring in practice may, within limits, be obtained. The friction of the journal is conveniently read off on a scale beam.

The Steam Engines. — We pass on now to the steam engines. The first of these are two of comparatively small size which were presented to the Laboratory by Messrs. E. Leonard & Sons, London, Ontario. These engines are used almost exclusively for exercises in valve setting and have cylinders 6 in. and 7 in. in diameter respectively, and 8 in. stroke, but have different types of slide valves. The one to the south has the ordinary D form of valve and a special design of eccentric by which the angle of advance and the throw of the eccentric may be independently varied. The other engine has a special type of inside admission valve which is partially balanced and so designed that



Thermodynamic Laboratory—Two Leonard Engines for Valve Setting

Thermodynamic Laboratory—De Laval Steam Turbine, Small Rooms in Background

the engine may be operated without the steam chest cover and thus show the motion of the valves; this engine has an eccentric of the same type as the one just described.

Both of these engines are fitted with throttling governors and suit the work for which they are designed exceptionally well, the kindness of the donors being much appreciated.

Next to these is a 15 H.P. de Laval steam turbine built by Greenwood & Batley, Leeds, England. As is the case with most of the other machines, this turbine has been specially arranged for experimental work and has six nozzles altogether, some of which are for non-condensing operation and the others are used when running condensing. The rotor of this turbine runs at a speed of about 24,000 revolutions per minute, the power shaft running at one-tenth of this speed. This turbine has been found very useful as an experimental machine.

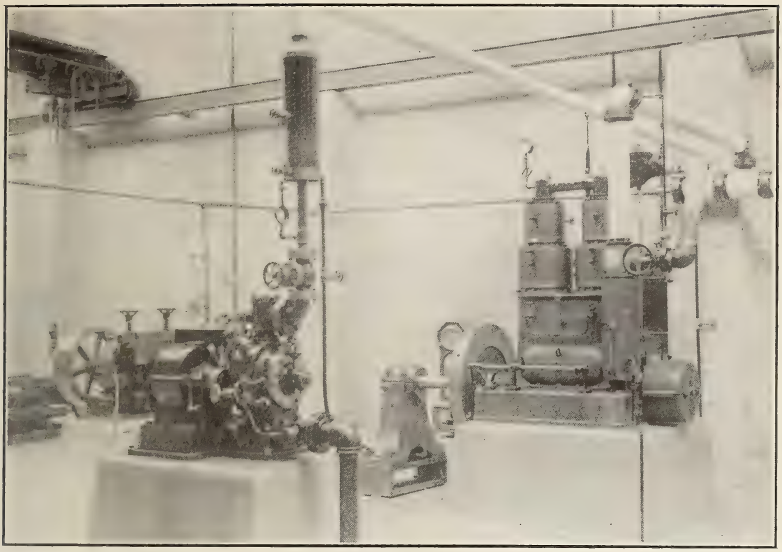
Behind the turbine is a Willans vertical, high-speed compound engine. This machine was purchased to drive the turbine pump in the old laboratory, but with the building of the new one an extra pump had to be installed so that a larger engine had to be purchased to supply the necessary power and the Willans engine became available for experimental work. It is of the high-speed type, having a normal speed of about 460 revolutions per minute, and developing at this speed 75 H.P. with a steam pressure of 125 pounds per square inch.

The design is rather peculiar as there is no valve gear evident externally. The piston rods are hollow and the piston valves are operated by eccentrics forged solid to the crank pin. In this particular engine there are two high pressure and two low pressure cylinders, the high pressure cylinders being above the corresponding low pressure ones; all are single-acting and in order to prevent shock on the crank at the end of the stroke there is an air piston below each pair of cylinders, the pressure of the air compressed by it being sufficient to make a continual downward thrust. The crank bearings have no upper cap and require none for the above reason.

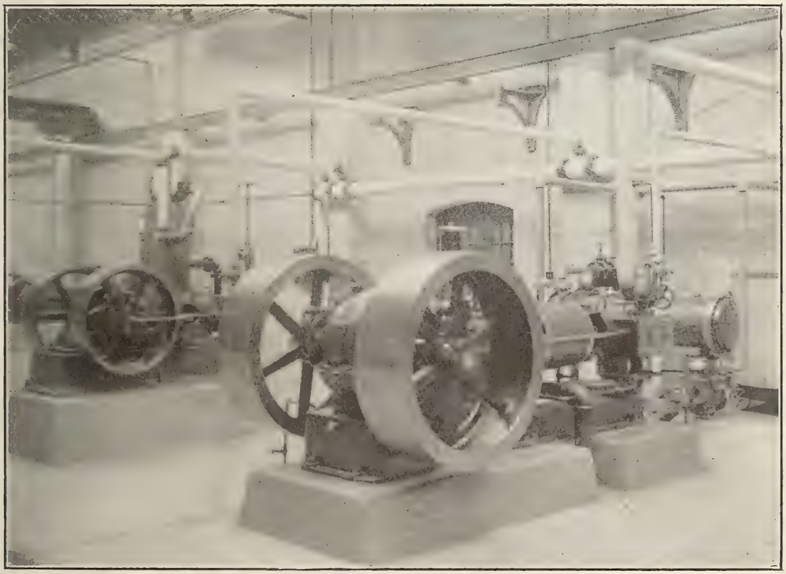
The steam cylinders are respectively 10 in. diameter and 14 in. diameter, and all pistons have a stroke of 6 in.

Engines of this type have met with great favor in England because of the low steam consumption, a paper by Mr. Willians read before the Institution of Civil Engineers in April, 1893, giving some very valuable information along this line.

A passage leading to the door separates these engines from the McEwen high speed horizontal engine. The cylinder is 8 in. diameter and 7 in. stroke, giving 18 H.P. This engine has a good form of shaft governor so that it is well adapted to instruction in the use and action of such governors, as well as providing good indicator practice. As it is connected like the other machines to the surface condenser, tests on the economy of the machine may be conveniently made.



Thermodynamic Laboratory—Steam Turbine and Willians Engine



Thermodynamic Laboratory—Tandem and High Speed Engines, also Surface Condenser

The Leonard-Ball tandem compound engine is also provided with a shaft governor of different type from the one mentioned above. This engine is horizontal and has cylinders 7 in. and 12 in. diameter by 10 in. stroke and will thus develop about 29 H.P. at 250 revolutions per minute.

There are two types of valves in the engine, the one in the high-pressure cylinder being a Ball valve with double inside admission. The valve is partly balanced, gives rapid cut-off, and on account of the double parts has a comparatively small travel. In the low pressure cylinder a balanced D slide valve is used.

This engine provides instruction in the tandem type of machine as well as practice with a shaft governor.

Next to the engine just described is the air compressor, a machine built by the Canadian Rand Drill Co., Sherbrooke, Quebec, and purchased through Mr. Haight of the class of '96 at one-half the actual commercial selling price. This machine is of the cross-compound, steam-driven, two-stage type, having the low pressure air cylinder arranged tandem with and behind the low pressure steam cylinder, and the high pressure steam cylinder in front of the high pressure air cylinder. The steam cylinders are respectively 9 in. and 16 in. diameter, while the air cylinders are 9 in. and 14 in. diameter, all having the same stroke of 12 in.; the normal speed is 160 revolutions per minute and the rated capacity 340 cu. ft. of free air per minute, with a steam pressure of 125 pds. per sq. in.

The fly-wheel is arranged with inside flanges so that a brake may be applied to it, and by disconnecting the air cylinders the whole may be run as a cross compound steam engine. Both steam cylinders are provided with Meyer cut-off gear, giving considerable elasticity.

The low pressure air cylinder has Corliss inlet gear and pressure gauges and thermometers are arranged for experiments of various kinds.

An air receiver is installed and piping runs to the milling building, delivering air when required to drive a rock drill.

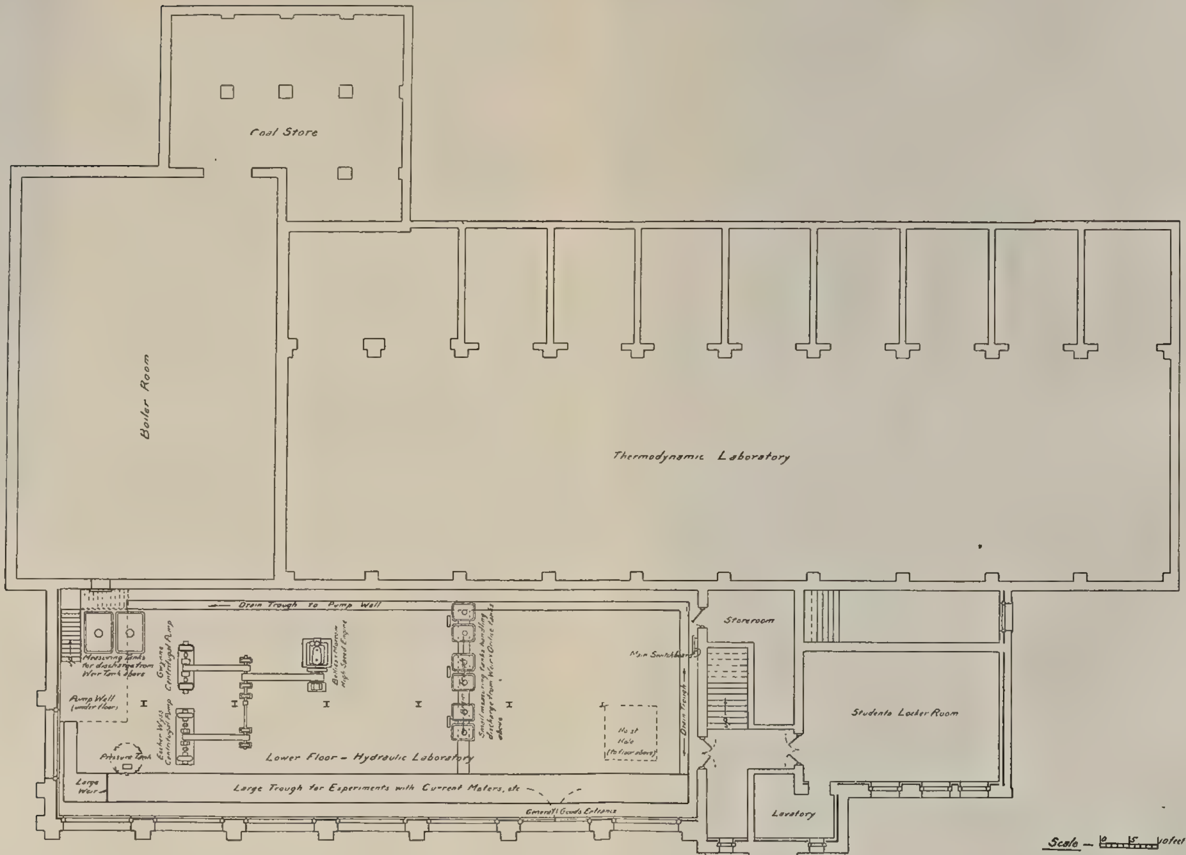
This machine is of great value and usefulness and forms a very good piece of experimental apparatus.

When the Engineering Building was opened it contained a 50 H.P. Brown automatic cut-off engine built by the Polson Iron Works, Toronto, and this engine has been set up again in the new laboratory. It is of special design for experimental work and has jackets on both heads and on the barrel, all jacket drains being separate in order that the condensation in each part may be independently determined. The clearance volumes in this particular machine are also made specially small and it runs quite economically.

The Steam and Exhaust Piping. — An examination of the photographs will show the general arrangement of the steam piping. It consists of a single line of 5-in. pipe running through

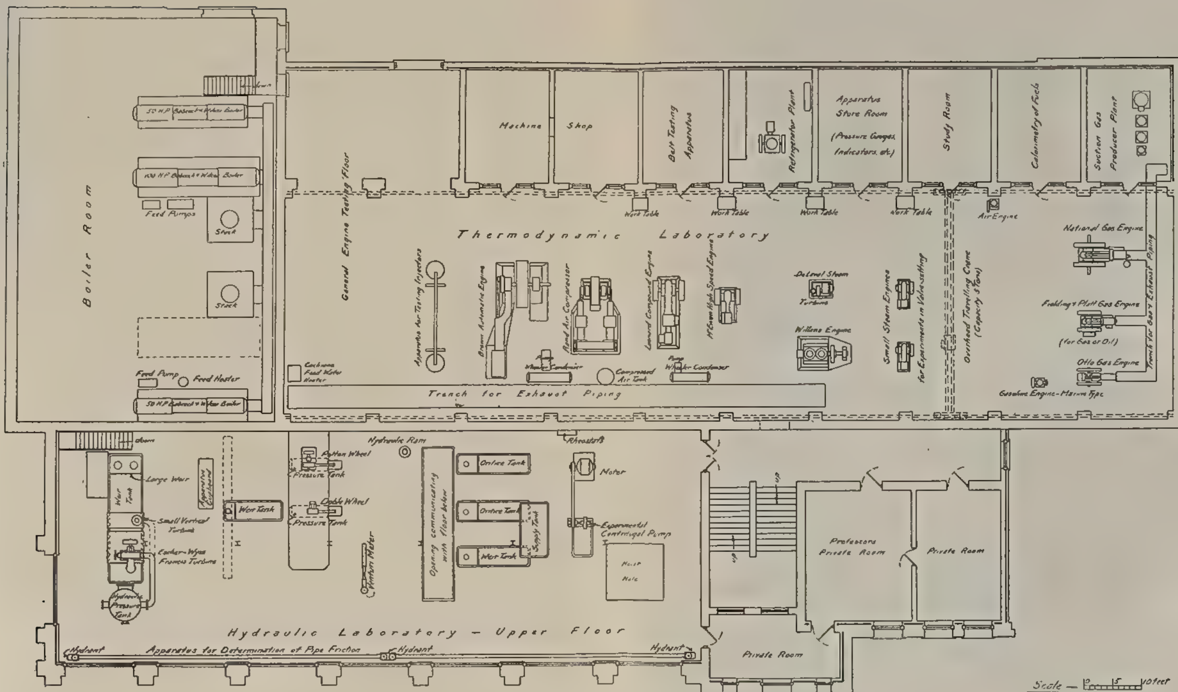
University of Toronto—Steam, Gas and Hydraulic Laboratories

Showing Basement of Hydraulic Laboratory and Foundations of Other Parts



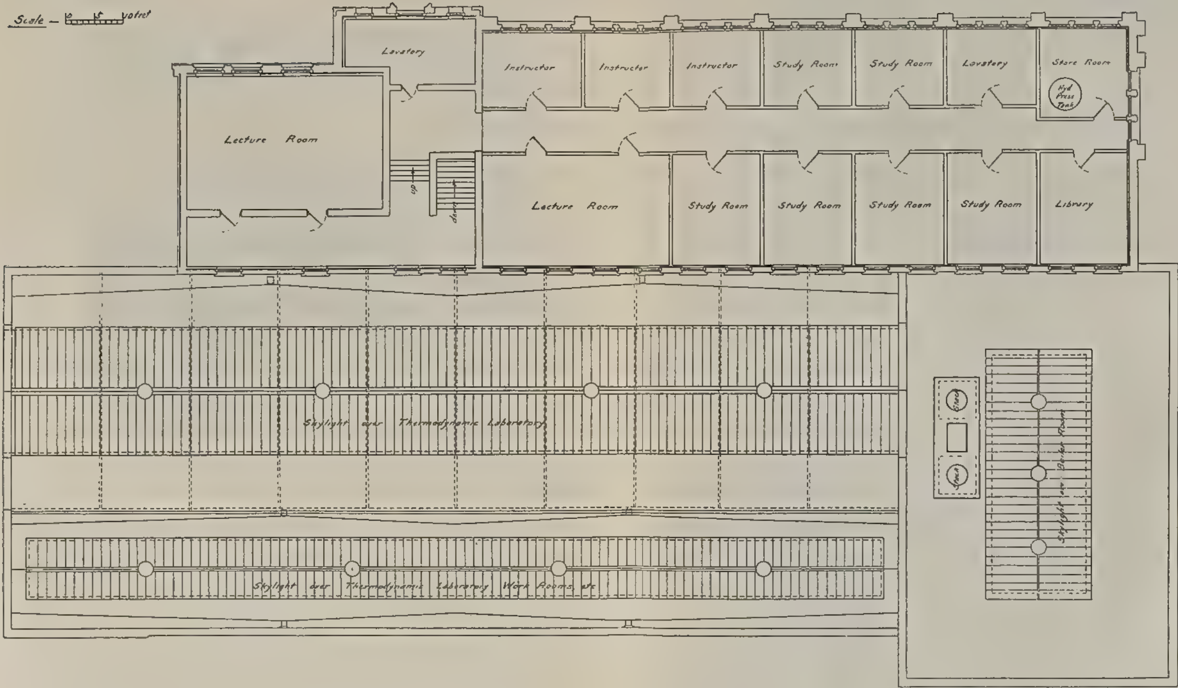
University of Toronto—Steam, Gas and Hydraulic Laboratories

Showing Boiler Room, Thermodynamic Laboratory and Top Floor of Hydraulic Laboratory



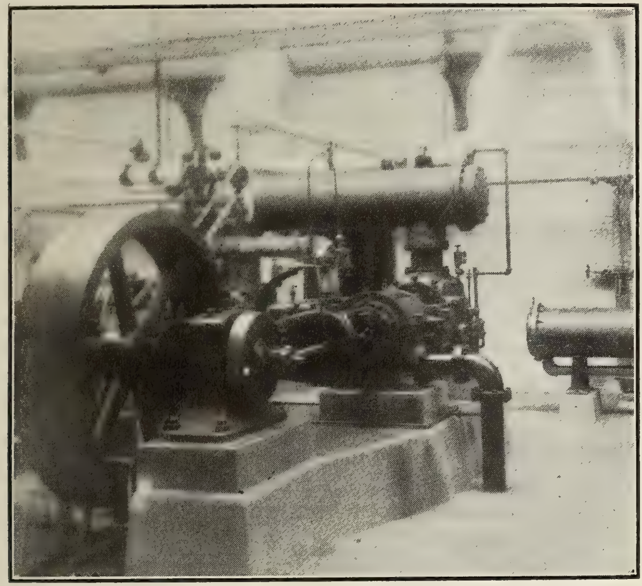
University of Toronto—Steam, Gas and Hydraulic Laboratories

Showing Study and Lecture Rooms over Hydraulic Laboratories



the boiler room and about 90 ft. along the wall of the Thermodynamic Laboratory, also of a 3½-in. pipe running from the northerly boiler up to the Brown engine connection. The latter pipe is designed so that it is possible to run a complete engine and boiler test on the Brown engine and the one 50 H.P. boiler. Connections are also made so that this boiler may deliver steam to the 5-in. pipe and the Brown engine may also be arranged to draw from the same pipe.

The 5-in. pipe has two large expansion bends, the one near the Brown engine being distinctly visible in the photographs. All connections on this line are flanged and each engine draws



Thermodynamics Laboratory—Air Compressor and Surface Condenser

its supply from the top of the pipe, thus avoiding water from drainage and condensation.

All engines are arranged to run either condensing or non-condensing, two surface condensers with independent air pumps being installed for the former condition of operation. There are two 6 in. exhaust pipes, one of which is connected to the condensers, the other through the heater to the atmosphere. Both of these are arranged with flanged connections and the system is so designed that by the removal of a few bolts any engine may be changed from the atmospheric exhaust to the condenser in a very short time, it being only necessary to change one blank flange and turn an elbow through 180 deg. The operation is thus accomplished without the use of valves and the measurement of the condensed steam becomes at once

accurate. The system also permits the running of almost any pair of engines condensing and at the same time the operation of all the other engines non-condensing. Proper drainage is provided for all piping and it has all given perfect satisfaction up to the present time.

The cooling water piping is shown below the steam piping but possesses no special features.

Brakes. — The writer believes that brakes should be of the simplest form possible so that students get accustomed to the handling of the cheapest and most accessible types. The brakes used are therefore rope brakes or else simple forms of the Prony brake, the wheels being generally provided with inside flanges so as to avoid annoyance from the cooling water.

The remainder of the space in this part contains a test floor which permits any engine submitted for test to be easily set up and run either condensing or non-condensing. There is also a space for the testing of injectors, these being arranged on a convenient and neat pipe stand ready for operation.

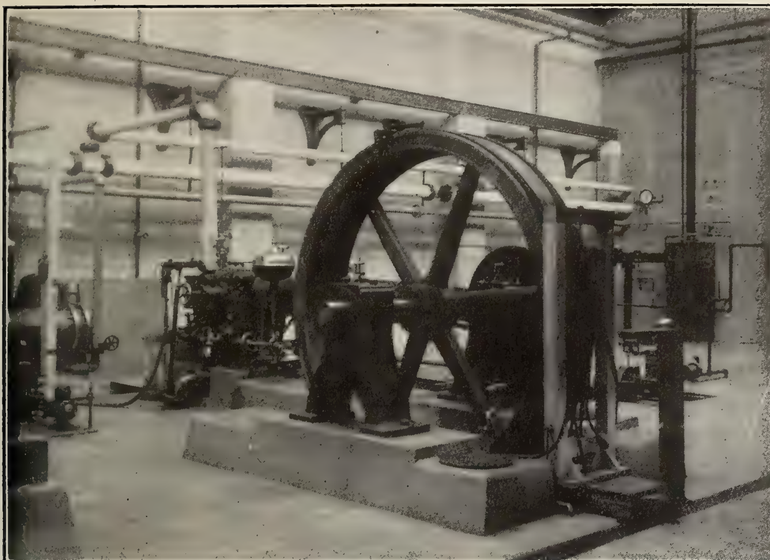
At the end of the room is a Cochrane Feed Water Heater purchased from the Canada Foundry Co., Toronto.

Some space has been left at this end of the room for expansion and it is hoped that in the near future a triple expansion engine will be installed here.

Small Laboratory Rooms. — The narrower southerly portion of the Thermodynamic Laboratory (with the exception of the two end bays which are used for delivery and unpacking) is divided into eight small rooms for special work of various kinds. The first two rooms are connected by a door and are used as a small repair and instrument-making shop, in which special apparatus is made as required. This shop contains a new 20 in. Bertram engine lathe of modern construction built by John Bertram & Sons, Dundas, Ont. There is also a 20-in. McDougall drill, an emery wheel and a wood-turning lathe together with a good equipment of tools. The shop is driven by a Westinghouse motor.

The third room will contain the apparatus for testing various machine elements and the methods of power transmission. For this purpose a torsion dynamometer has been purchased from J. Amsler-Laffon & Sohn, Schaffhausen, Switzerland, which may be used for the transmission of any power not requiring over 540 ft. pds. twisting moment. As the machine may be safely run at high speeds its possibilities in the way of power transmission are fairly great, and it thus serves as a very flexible instrument. This instrument will be used to deliver a measured quantity of power to a belt or rope or any form of bearing or machine element, and the efficiency of the transmission or the element may be directly determined by absorbing the power by a brake at the driven end.

The fourth room contains a refrigerating machine of three



Thermodynamic Laboratory—Brown Engine, with Feed Water Heater in Background

Thermodynamic Laboratory—Refrigerating Machine and Equipment

tons capacity, built by the York Manufacturing Co. of York, Pa. It is of the ammonia compression type and the horizontal steam engine and vertical compression machine are connected to the same crank. The complete accessory equipment has been provided and arrangements made for indicating the steam and ammonia cylinders and for taking the temperature at every desirable point in the plant.

The next room has been set apart for instruments and in it are kept all of those used in both the Thermodynamic and Hydraulic Laboratories. All instruments are given out to students on application by ticket and are charged up against the one receiving them. When an instrument is returned it is examined and if in proper condition is put in its place, but if found to have been damaged by the student the cost of repair is charged against him. By this system careless handling or loss of instruments is avoided.

The sixth room is used as a Third Year study room while the seventh is to be used for the testing of lubricating oils and the determination of the heating power of gases and fuels of various types. A Sargeant gas calorimeter has been purchased and is to be used in this room.

The last room is occupied by the suction gas plant, described earlier in this article.

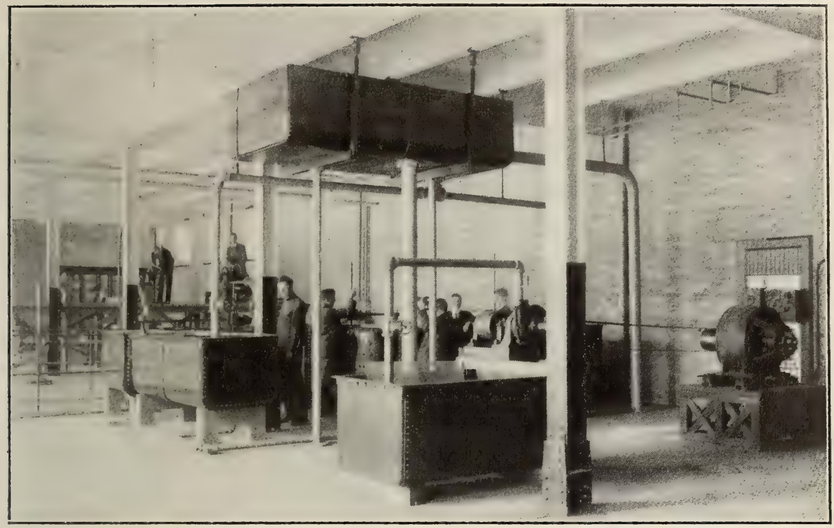
Just in front of these rooms and secured to the crane piers a number of tables have been placed on which work on gauge and indicator calibration may be carried out, the gauge calibration being done by Crosby gauge testers, while the indicator springs are calibrated by means of steam supplied at various pressures.

The whole of the larger part of this laboratory is served by a three-ton travelling crane of about forty feet span. This crane is operated by hand and has proved of inestimable value in the placing and handling of the different pieces of apparatus.

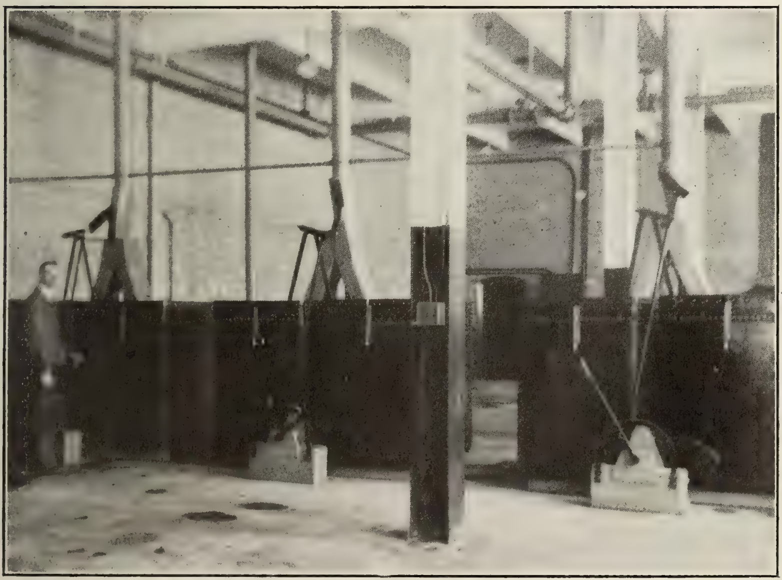
The Hydraulic Laboratory.

The Hydraulic Laboratory occupies the north half of the building and is located in the basement and ground floors, each of which is 40 ft. wide by 113 ft. long. The light for this laboratory had to be obtained from the north and east, and as only one large window could be placed in the east end, the north light had to be depended on almost entirely. Large windows running up the full height of the two laboratory storeys were designed, which take up three-quarters of the entire side of the building. This gives a good architectural effect and while not giving as good light as is obtained from the roof in the Thermodynamic Laboratory, yet it is quite satisfactory.

On account of the large area of glass exposed to the north, trouble was anticipated in the way of heating the building and



Hydraulic Laboratory—General View of West End of Top Floor



Hydraulic Laboratory—Orifice and Weir Calibrating Tanks in Basement

arrangements were made to put double windows throughout, which, however, have not been necessary.

The lower storey or basement is 18 ft. high and contains the well, the pumps and the engine for driving them, the measuring tanks used for calibrating the orifices and weirs above, several large troughs and the main part of the piping for the entire laboratory, while the upper floor, which is 15 ft. high, contains the orifice and weir tanks, the experimental centrifugal pump with its weir tank and motor, the various pipes for friction experiments, the meters, and also the various types of turbines and other apparatus.

Beginning with the top floor at the west end, part of the space had to be left clear for a hoist hole, the first piece of apparatus being a centrifugal pump of special construction for experimental work. This pump was designed along theoretical lines and has carefully polished vanes on the runner; it is mounted on a weir tank so that the discharge may be very easily measured, the various heads under which it is operated being obtained by throttling. The pump is driven by a variable speed motor by means of which the power put into the pump may be determined and its efficiency readily obtained. The arrangement has been found very satisfactory as it gives the student an opportunity to study the effect of variations in speed, discharge, pressure and efficiency of the machine.

Adjacent to this are two orifice tanks and a weir tank used mainly for instruction in the use of orifices and weirs. Various sizes and shapes of orifices are inserted and operated under several heads as measured by hook gauge. The water is discharged through 6-in. pipes into the calibrating tanks below, of which there are six, two for each orifice and weir, each tank having a capacity of about 50 cu. ft.

These calibrating tanks are of some interest and have been carefully designed so as to be entirely operated by the movement of a single lever. When the lever is put in one extreme position one tank is made to fill, its outlet valve being closed, while the outlet valve of the other tank is at the same time open. For the small discharges the tank fills so slowly that the upper surface is quite smooth and undisturbed and therefore the exact height of the water in the tank, and consequently the volume of the water at the moment of dumping is easily observed, but where the discharges are large the surface of the water in the calibrating tank is so disturbed that accurate observations of this kind are impossible. To obviate this trouble the mechanism is so designed that by moving the lever to an intermediate position the outlet valve on the other tank is closed and the discharge turned into it, the water surface in the first tank coming to rest at once its height is easily observed, after which the lever is pushed to the other extreme position, the outlet valve of the first tank being thus opened without disturbing the conditions in the second tank.

The quantity of water in the tank after filling may be found by direct weighing or by reading the level in an attached gauge glass.

The floor has been constructed with an opening protected by a rail, so that the student may observe the whole operation at one time and thus get a clear idea of the process of calibration.

In order that experiments on these tanks and orifices may be carried on without interfering with the other work, a large reservoir, provided with an overflow, has been placed above them, and from this they draw water. So long as there is enough water passing into the reservoir to cause some overflow the experiments may be carried on at various heads and discharges without difficulty.

From this reservoir a 1¼-inch pipe is also run to a hydraulic ram which can thus be operated under a head of about 10 ft. and with a drive pipe about 40 ft. long.

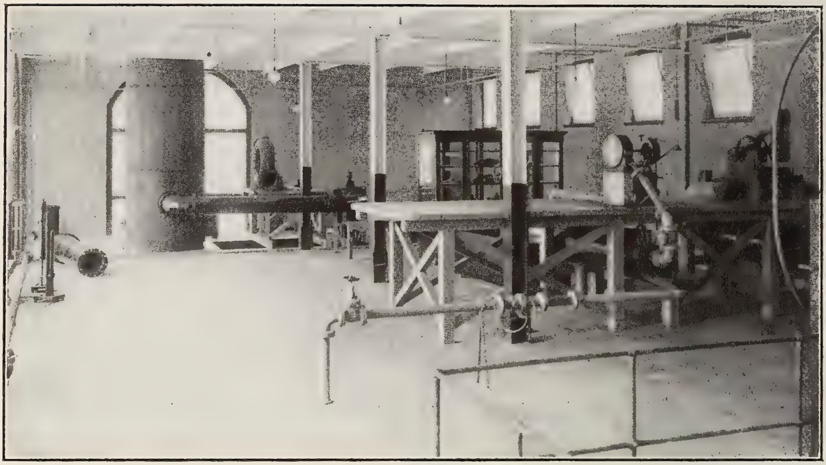
A three-inch Venturi meter has been installed on a pipe in which other meters will also be placed. This meter is rated by sending the discharge from it through one of the orifice tanks already described, using the coefficients determined by actual experiment.

A little to the east of the centre of the laboratory an elevated platform about 25 ft. long and 7 ft. wide has been erected for the impulse turbines. At present two turbines are in use, one a Doble wheel made by the John McDougall Caledonian Iron Works, Montreal. This is a very well finished wheel of 12 in. dia., and as it has glass sides the action of the water may be very conveniently studied. The needle regulating nozzle gives a very perfect stream.

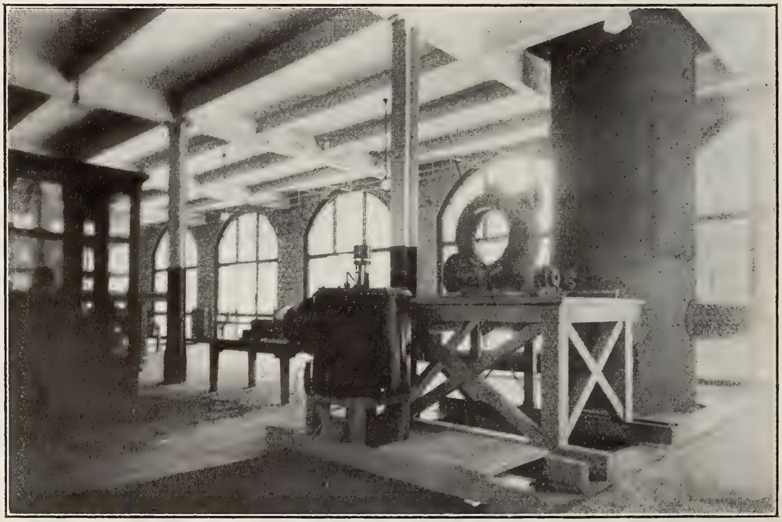
The other machine is an 18-in. wheel made by the Pelton Water Wheel Co., and although not so well constructed, it represents a very common class of water-wheels in use to-day.

The water used by these turbines is measured by passing it through a weir tank and then back to the pump well. For the use of these turbines it is possible to get a discharge of 1 cu. ft. per sec. against a maximum head of about 500 ft.

At the east end of the room is a large stand-pipe 32 ft. high and 5½ ft. dia., supported on a stand in the basement so that it reaches up into the roof of the building. This stand-pipe is used as a reservoir for the reaction turbines and also for any experiments requiring constant but not very high heads. This stand-pipe has a 14-in. nozzle on each side for the attachment of turbines and also a large nozzle 30 in. dia. on the front so arranged that orifice plates and tubes of various sizes may be attached and experiments made at higher heads than is possible in the open orifice tank. The water is delivered to the stand-pipe through two 8-in. pipes near the bottom and by a convenient arrangement of baffle plates there is no trouble caused by the surging or eddying of the water.



Hydraulic Laboratory—General View of East End of Top Floor



Hydraulic Laboratory—Top Floor Showing Reaction Turbines, with Weir Tank and Reservoir

In front of this stand-pipe is a large weir tank 20 ft. long by 6 ft. wide, which is arranged with a sharp crested weir 4½ ft. wide with end contractions. This plate may, however, be changed so that weirs of different sizes, with or without end contractions, may be easily inserted. The total depth of the tank is 3 ft. 9 in. and the depth of water below the crest of the weir is 2 ft. 3 in.

The weirs used in this tank may also be calibrated by means of a pair of measuring tanks in the basement, each holding approximately 240 cu. ft. and both being connected to the weir tank on the down stream side of the weir by 12-in. galvanized iron pipes. Hydraulically operated valves are to be used in connection with these calibrating tanks and are so designed that a single lever is made to do the whole operation of filling and emptying as in the case of the smaller tanks already described. This lever, as in the former case, has three positions when operating, the extreme positions indicating that one tank is filling and the other emptying, while the intermediate position is used when both discharge valves from the tanks are closed and one of the tanks is filling. It is believed that very accurate coefficients can be determined by this method.

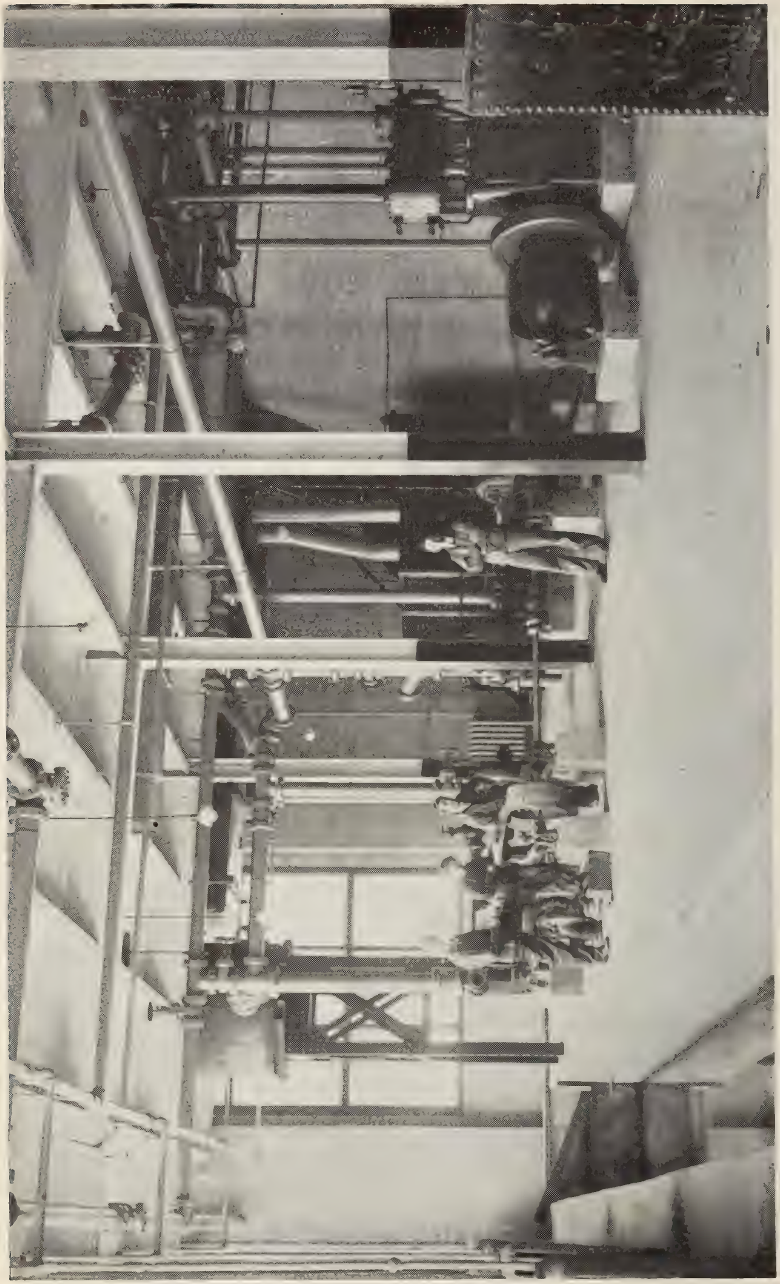
There are three reaction turbines available for testing. The smallest one has a 6-in. runner and was made by Wm. Kennedy & Sons, Owen Sound, Ont. It has been set up in a steel penstock and connected to the stand-pipe by a 14-in. steel pipe containing two elbows. This pipe is to be used for experiments on the flow through elbows, the conditions being examined by a Pitot tube. This 6-in. turbine has been operated under a total head of over 25 ft., including about 5 ft. in the draft tube. The horse-power is measured by Prony brake and the discharge is determined from the 4½ ft. weir.

A 9-in. McCormick turbine with cylinder gate has not been set up but is left to give the student practice in the measurement of such wheels and to enable him to study the forms of the vanes.

The latest turbine to be installed is one purchased recently from the noted hydraulic firm of Escher, Wyss & Co., Zurich, Switzerland. This wheel, of the horizontal Francis type, has a well designed spiral casing and a runner nearly 14 in. dia. The gates are of standard design, operated through a ring by a hand wheel on the casing. A conical draft tube over 7 ft. long is used and the wheel will deliver 10 H.P. when supplied with 6 cu. ft. of water per sec. at a head of 20 ft. As this wheel is of the very best construction it forms an excellent addition to the experimental equipment.

The maximum quantity of water available for these reaction wheels is about 6 cu. ft. per sec.

Along the north side of this floor near the windows arrangements are made for the testing of the friction in fire hose and iron

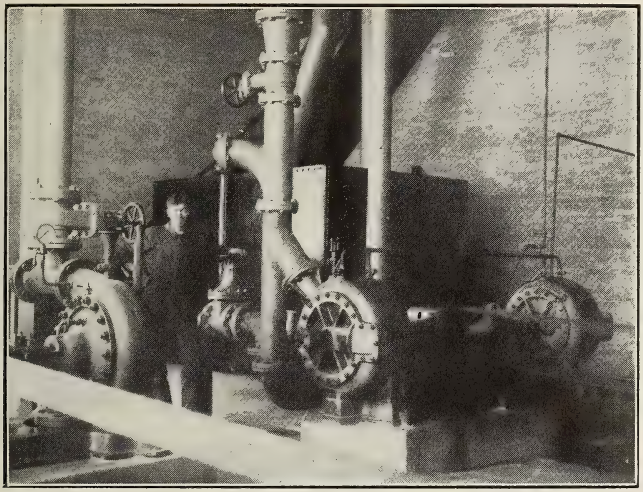


Hydraulic Laboratory—General View in Basement Showing Open Trough, Pumping Units, Engine, Etc.

pipe. A 2½ in. iron pipe 50 ft. long has been set up, also a 50 ft. length of fire hose, and the frictional losses are determined. The flow in the iron pipe is also studied by the Pitot tube, and curves showing the distribution of the velocity are plotted.

The basement contains, in addition to the orifice and weir calibrating tanks already mentioned, the well and pumping plant. All water used in the laboratory is drained back to a large well from which it is pumped into the system and used over and over again.

There are two sets of turbine pumps used for this purpose, one of which was built by Messrs. Gwynne, London, England, and the other by Escher, Wyss & Co., Zurich. Each set consists of two two-stage pumps fastened to a common bed plate and driven by a single pulley, couplings being arranged so that either pump may be separately operated. Further, the two



Hydraulic Laboratory—The Two Pumping Units

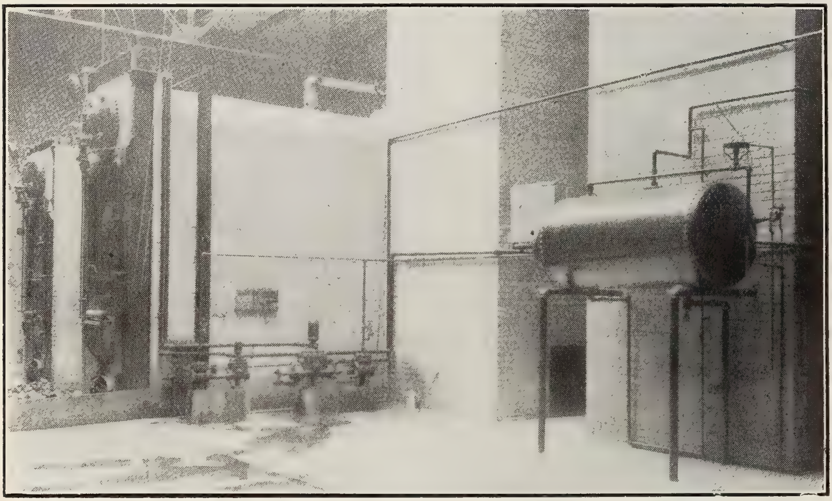
pumps on the one base are piped together in such a way that they may be made to deliver into the piping in three ways, viz., (a) separately, (b) in series, (c) in parallel. A connection is also designed to connect the discharge from the Gwynne pump to the suction from the Escher-Wyss pump, putting the two sets in series for very high pressure work.

Each of the Gwynne pumps will deliver 1 cu. ft. per sec. against 125 ft. head, while the other pumps have the same capacity against 150 ft. head, the discharge at lower heads being, of course, much greater.

As suitable piping has been arranged in the laboratory, it may thus be seen that the whole arrangement of the plant is very flexible, permitting (a) the operation of the four pumps

separately, thus allowing four absolutely independent experiments at one time; (b) the operation of the two sets separately on separate experiments; (c) the operation of the two sets in series for high pressures and moderate discharges as are required in fire streams and impulse turbines, giving 1 cu. ft. per sec. at 500 ft. head; (d) the operation of the two sets in parallel giving about 6 cu. ft. per sec. at the heads available in reaction turbine work in the laboratory.

The pumps are of modern design, the Escher-Wyss set having been installed during the fall. They run at speeds of 1,300 and 1,400 revs. per min. respectively, and are belt-driven from a jack shaft placed on the floor, vibration of the building being thus entirely avoided. The jack shaft is driven by a Belliss Morcom engine of 130 H.P. running at 530 revs. per min. This



Boiler Room—Only Two Boilers and Two Stacks Shown

engine is a very fine piece of workmanship and runs quietly and without vibration. The exhaust from the engine is used to heat the building.

Arrangements are being made for the insertion of a transmission dynamometer in the Escher-Wyss pump drive so that its efficiency may be determined with greater accuracy than can be obtained by indicating the engine.

A large trough 6 ft. wide, 4 ft. deep and 110 ft. long has been provided in the basement which is used for the rating of current meters and tubes and other work of this nature. It is believed that this will be especially useful in view of the rapid power development going on in Canada at the present time.

There is sufficient space still left for further expansion.

The Boiler Room.

This room contains three Babcock and Wilcox boilers, all built for 200 pds. pressure.

The 100 H.P. boiler is provided with a superheater while the two 50 H.P. boilers have been set up independently and one is arranged with a special type of setting so that valuable comparative results may be obtained.

A separate feed pump is provided for each boiler so that separate tests may be made on each one.

A steel breeching conducts the products of combustion to the stacks, of which there are two of brick, each 100 ft. high and 36 in. internal diameter. An arrangement of dampers allows these stacks to be operated at different powers on the same day and thus reliable experiments may be made on the capacity of each stack.

The room is light and airy, being 70 ft. long, 45 ft. wide and 26 ft. clear height. All the light is obtained from the roof and is very satisfactory indeed.

Offices and Study Rooms.

An examination of the accompanying plans will show that at the north-west corner of the building, immediately west of the Hydraulic Laboratory, there is a further space partly occupied by the stairways and halls and partly by other rooms. These rooms are as follows: In the basement, the students' room with shower bath, on the first floor the professor's and the lecturers' rooms while the top floor is occupied by a lecture room and private lavatory.

An entire floor above the Hydraulic Laboratory is divided up into students' study rooms, a lecture room, a library, demonstrators' rooms, and students' lavatory. All of these rooms are comfortable and bright and the students' rooms are provided with convenient tables and a locked drawer for each person.

Artificial Lighting.

The large Thermodynamic Laboratory is lighted by ten Nernst lamps, which are attached to the trusses and provide sufficiently good light to do any work required. The Hydraulic Laboratory is lighted by tungsten lamps, there being ten to each floor.

The remainder of the building, with the exception of the boiler room, which also has a Nernst lamp as well as incandescent lamps, is lighted entirely by incandescent lamps, which seem to give very good satisfaction so far.

Conclusion.

This article would be incomplete without making mention of the work of Dean Galbraith. It was he who gave the

writer his first real insight into the profession which he honors and it is on the foundation laid by him that the writer has built in striving to design a laboratory that shall give the future engineers the proper basic principles on which their life work depends. The teaching of principles is vastly more important than the teaching of a few facts, the desire to teach these principles in such a way as to make the practical application clear is a thing for which Dean Galbraith has always stood, and the writer's association with him and with the engineering world have given him the desire to make the laboratories described such as shall be a real help to the student when he gets into active practice.

Acknowledgment is also made of the help given by the members of the staff in Thermodynamics and Hydraulics who assisted by many suggestions and by the sacrifice of much time in making the building and equipment such as it is.

It will be noticed that all of the units in the two laboratories are comparatively small and are such as can be handled with comparative ease. The writer believes this to be a valuable feature of such a laboratory, as the student can readily comprehend the whole machine at one time, and therefore does not lose the connection between the different observations as he is apt to do with the larger units where the parts are so much separated. The results obtained are, the writer believes, quite as valuable, from the point of view of the instruction to the student, when obtained from reasonably small machines as from very large ones.

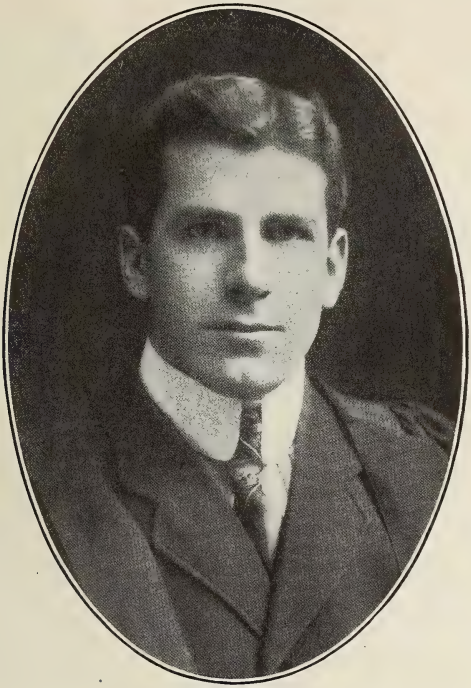
No machine in the laboratory is used for electric power or for any other than experimental purposes, so that all pieces of apparatus are always available for experiment or research.

THE ANNUAL DINNER.

Convocation Hall, January 19th, 1910

The one social event of the Engineering Faculty is the annual dinner of the Engineering Society. It is always looked forward to with considerable pleasant anticipation, and thanks to good management and enthusiasm, is always looked back to with considerable pride. Each succeeding president of the society and his executive have strenuously endeavored to make their annual dinner just a little better than its predecessor. This year their efforts were again crowned with success.

The dinner has always been used as a medium of connection between the University and the commercial world. Last year



W. D. Black, President of Engineering Society

advantage was taken of the fact that the Canadian Society of Civil Engineers were meeting in convention in Toronto. They were invited to be the guests of the Society and to the number of two hundred attended.

This year one question which looms large in the field of commerce is industrial education. In the world of commerce the race for supremacy is each year becoming keener. The weak are being constantly pushed to the wall. The raw materials are becoming scarcer, and conservation, the making the most of

all resources, is the watchword. Germany has long recognized the old maxim that in knowledge is strength and now it is generally recognized that industrial success must in a great measure depend on technical education. Canadian interests have at length awakened to the need of advancement along the lines of industrial education.

There has been and is still a lamentable lack of intercourse between the Canadian industrial corporations and the universities. It would be interesting to know the reasons for this. Does it lie in the conservatism of the manufacturer, or in the inefficiency of our graduates? Assuredly not the latter, for our men go across the line and hold their own with the best. In all departments but mechanical and electrical, our graduates are being readily absorbed in the development of the country, but in these two, the men are drifting to the United States and are a serious economic waste to Canada. Some Canadian industries, it is true, are using a large number of our graduates, but these are in most cases Canadian branches of American corporations.

With a view of interesting the captains of industry more intimately in the university, and to gain their sympathetic and active co-operation in the solution of the problems of technical education, it was thought advisable this year to invite the members of the Canadian Manufacturers' Association to be the guests of the Society at their twenty-first annual dinner on Wednesday evening, January 19th.

The dinner was a complete success from all standpoints. The undergraduates were at their best, lively with song and jest in their contributions to the programme, but strictly attentive to the various addresses.

The guests from the Canadian Manufacturers' Association, together with the graduates, numbered about two hundred. The student body swelled the attendance to seven hundred.

W. D. Black, president of the Engineering Society, occupied the chair. In a brief speech he welcomed the guests of the evening and proposed the toast, "The King," which was received with an enthusiasm characteristic of School men.

The toast to "Canada and the Empire" was introduced by A. G. McLeish, who after giving voice to the loyal sentiments and aspirations of the students, called upon J. A. MacDonald, LL.D., to respond. Dr. MacDonald spoke as follows:

J. A. Macdonald, LL.D.—

My purpose to-night in responding to your toast is very simple. Representing as you do the trained intelligence of the University, devoted as you are to the application of the great sciences to the great arts, and having as your guests so many men of prominence and leadership in the great industries of this country, I make no apology for venturing a few words of warning against evils and abuses which must be taken out of the way or Canada will never come to its own, and the Empire will

not remain united and strong. My warning is against the waste, the disastrous and wicked waste, which has marked centuries of Britain's history, and which, unless the warning is heeded in time, will do irreparable damage to Canadian interests.

(1) I speak first of economic waste alike in Canada and in Britain. Take the outstanding British instance. The great source of wealth is land. Out of the earth and the products of the earth comes the wealth of the people. Food and clothing and all the sustaining and comforting necessities of life depend directly or indirectly on the uses of the country's natural resources. The roots of all great enterprises and institutions are in the soil. But see what happened in Britain. God made the land for the people, but the people were not wise or were not wisely led, and now it is asserted that eighty per cent. of all the land of Britain is held by three per cent. of the people. One-quarter of all the land of Scotland is owned by twelve persons. One man owns in Scotland alone 1,300,000 acres.

J. A. Macdonald, LL.D.

But the economic waste is not so much in the limited ownership of the land as in its non-productive uses. Literally millions upon millions of acres suitable for agriculture are declared by competent and responsible authority to have been turned over to the sports of the few. That situation has become worse, instead of better, as the population of Britain has increased. Within one certain period of five years 700,000 acres of moor and bog-land in Germany were reclaimed and put to agricultural uses. Within the same five years 2,000,000 acres in Britain were withdrawn from agriculture and devoted to grass and deer forests. How can a country hold its own with such deliberate and wilful waste of its chief source of economic wealth?

But has Canada the right to boast? We know how things look in the United States. We know something of the colossal theft and graft that have already cost the people of the United States the control of their natural wealth in land and mine and forest and sea. If Mr. Pinchot's dismissal by the Executive at Washington leads to a complete exposure he will not have been sacrificed in vain. But if we knew all the facts of the

Canadian situation we might find cause for alarm. Certain it is that all over this country the resources and opportunities of public wealth have been alienated to private monopoly. Mineral lands, forest areas, fishing rights, water powers—all these have been coveted and many of them have been captured by private individuals on terms unjust as those that governered the granting of great areas of Britain to favorites of the court. Had it not been for the protests, chiefly of the press, every volt of electric energy of Niagara Falls would long ago have been controlled by some private electric trust or merger. Unless there is eternal vigilence on the part of the public and in Parliament the economic advantages of Canada will yet be largely conducive to private wealth at the expense of public service.

For this reason the very greatest public interests are involved in the work of the Commission on the Conservation of Canadian Resources now in session at Ottawa. In all such work of creating sound and active public opinion in this subject of economic conservation and waste this society and this university, and the various industries represented here to-night, should have a large and influential share.

(2) A second word of warning is against the social waste which has marked Britain's life for centuries. Social waste is an inevitable resultant of economic waste. If a few men control the great sources of wealth and the means of wealth, it must be at the expense of the many who have no adequate chance. The crowding of the people off the land into the towns and cities helped to create and to continue and to aggravate social degeneration and decay. The situation in British cities with their landless people is the correlative of the situation in the rural communities with their vast areas of peopleless land. There is no problem pressing more urgently for solution in Britain than does the problem of checking and curing this appalling waste of workers through social decay.

The same problem presses in Canada. There are everywhere, in every community, the physically and mentally unfit and inefficient. Poor blood, unsteady nerves, untrained minds, low and debilitating instincts—all these factors enter into the problem of a nation's strength. They make for that waste which saps the strength of society. In Britain the appalling drink habits of the people, the craze for sport and their mania for gambling, are causes of which Parliament at last begins to take account. The same problem is important in Canada. If it is neglected similar causes will produce similar results.

(3) My third warning is against the industrial waste which, if unchecked, must result in industrial defeat. Efficiency is the cry in the great centres of successful manufacture and trade. But in Britain to far too great a degree the economic waste and the social waste have resulted in serious industrial waste. In many respects the British manufacturer commands the world's admiration, but all students of British conditions see the enor-

mous wastage which long ago would have brought economic ruin but for those other masterful qualities of the British people which have made them the merchants of the world.

And here again Canada needs to be warned. Our almost unequalled resources in raw materials tempt us to be neglectful. In many industries the rights of labor and the conditions of labor are neglected. The standard and quality of labor too often are inadequate. Germany is awake to the importance of the best technical knowledge and the finest mechanical skill in her industrial enterprises. The United States spend lavishly on the training of their industrial workers. But both Britain and Canada have been slow to harness knowledge to their wheels of industry.

A beginning has been made, a splendid and hopeful beginning. Behind all the political confusion in Britain, which fills the air with dust and clamor, there is a deep and determined resolve to revise and to rationalize the education and training of those who are to man the mills and factories and workshops of Britain. If that resolve is carried out along large lines and with the Englishman's thoroughness, my word for it in twenty years, under favorable conditions, British factories and mills will more than hold their own against all foreign competition. British commerce will command the world's markets, and Britain herself will still be mistress of the seas.

In this new era Canada must play a great and determining part. Here is where the knowledge of laboratories and the skill of the schools are needed. With these vast resources conserved by law, the manufacturers of Canada should hold their own against the world. All they need is trained intelligence and vision in their management and the service and skill of the universities and technical schools in the workshops.

This is the call to this University. It is the call of Canada and the Empire. It is the call to fitness for Canada's great future—fitness in manhood, in knowledge, in purpose. You men of this University, it is on you and with men like you the destiny of your country hangs. Fit yourself for it. The Genius of Canada call to you. By your power and devotion to your plain duty you will help Canada stand with the Empire, one and undivided, and that one will become a thousand, that small one a strong nation, in the great day of crisis and of destiny.

On rising to respond to the toast, "The University," which had been proposed by E. R. Gray, the president, R. A. Falconer, received a most flattering reception, a reception which in a slight measure evinced to the guests the hold he has on the undergraduates of the university. Dr. Falconer said in part:

President Falconer:—

It is not an easy task to speak after such a reception as this, but I assume it is an expression of the unity of this university and the way we are seeking in each of the faculties one common

Twenty-First Annual Dinner, University of Toronto Engineering Society

end: to prove to the people at large that what they are doing for us is being appreciated, that expenditures are being wisely made, and that, instead of being wasted, the money we are spending is an investment of the highest order and of the greatest use to the country. The gentlemen from the Canadian Manufacturers' Association, and other leading and prominent gentlemen, have thrown their lives into this Dominion, and into this province, and I feel it is perfectly proper that the captains of industry who have shown their ability in practical affairs should realize what the university means to them. We should get encouragement from them in the work we are doing.

We hear a great deal about the conservation of our natural resources. We are told that unless we are careful in the management of these resources we shall, in the future, reap a sorry harvest. But, gentlemen, I believe there is nowhere that this lesson should be more emphasized than in the university, where we are training men who should go out and assist in the development of these resources. I am told that in Canada we have limitless natural wealth, that our water powers have not yet been measured, that our forests have illimitable supplies. What is the value of these resources? Resources are no resources until they are converted into use for men and women. The resources do not mean resources until human intellect has been applied to them. Gold is nothing as it lies hidden. Water power is of no use to humanity unless developed. These things are practically nothing apart from the men who fling themselves into their development. How can you reduce your ores? Is it by the chance laborer? Not so. It is by men trained to use a method. It is by the mining engineer who knows where to look for resources. It is by the electrical engineer who knows how to convert resources and by the mechanical and civil engineers who know how to construct. Further, it is reasonable in view of the cry of the daily press relative to the conservation of natural resources that this faculty should have gentlemen who realize the situation. The commission at work has its purposes—to hold investigations, to institute research work and to disseminate knowledge. Abstract thought is taught in the universities, but it works itself out in practical applications.

Men are greater than the land in which they work. The man who discovers a mine is greater than the pile of ore which, under his supervision, is heaped up.

The university has something to say with regard to immigration. We are face to face all through this country with the problem of labor. There are multitudes of people coming to this country from the old lands, with old ideas, old prejudices, old hatreds and old social conditions to which they are accustomed. And just as you study the natural resources and their conservation, you must study these resources that are living and vital. Where are they to be studied? In the university, I hope. In the

universities we must turn out men who are acquainted with the way the world has run its course, men who know how others have struggled. Further, gentlemen, we can justify ourselves as a university to the men interested in the welfare of this country. The students are the ones who are to justify to this province the position of this university. The country will look to you to understand what is being done here. They will expect of you, in your own localities, wherever you are located, to prove that the money spent in the university is well spent, that the work done is worth doing, and that we are able to produce results that count. You are the ones to explain what the university means. These gentlemen of ability and intelligence realize it.

A. D. Campbell, in proposing "Canadian Industries," indicated the relation of the university to the various industrial activities. He coupled with the toast the names of Louis Simpson, J. P. Murray and P. W. Ellis, three gentlemen representing as many phases of industrial enterprises. Mr. Simpson dealt with the recent progress made in the uses of electricity in smelting and the economic wealth resulting from the electric treatment of otherwise valueless ores. He pointed out that it is now nine years since the Dominion Government sent a commission to Europe to gather facts relating to the reduction of iron ores by electricity.

This commission is known all over the world as Dr. Haanel's Commission. The furnaces then in use were not suitable for the reduction of Canadian iron ores; but in the last year a furnace has been produced which is considered to be entirely commercially practicable. The product of these furnaces might be called a new metal, being intermediate in quality between steel and pig iron, while the cost of production is relatively the same as that of pig iron. Mr. Simpson also argued for the better industrial education of the farmers, and urged that the foundations be well laid in the public schools.

Mr. Murray, who has given considerable thought to the problem of industrial education, followed, Mr. Murray arguing for a broader technical education.

J. P. Murray:—

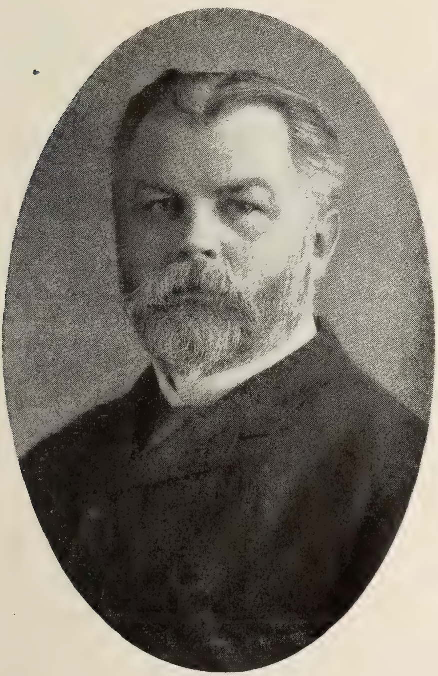
When we turn to the question of education, we admit that each child is not only entitled to the use of a school but we have enacted laws compelling his attendance therein. How far then are we to go with him in education? By what we are doing and in the doing of it, we acknowledge an obligation and at the same time we accept the responsibility of the obligation. We do in the province as is done in every town, big or little; i.e., tax the people for a school. In the town it is just a "school," but in the province it is a "university." Every boy in the town must attend the school, but only a favored wealthy few may attend the University, though all contribute to its support.

So far there is a marked evidence of favoring the wealthy,

or in other words, admitting that one class of the people has privileges over another. This is not the only instance of evidence that may be offered where a favored branch of the community has advantages over another branch. The farmers of the province not only have agricultural colleges to attend, but the professor in cheese and butter-making, etc., actually comes to his door.

The country youth who has ambitions for some sphere of life and activity other than that of the farmer, but who has not the good fortune to be born of wealthy parents, must be satisfied to plod along as an assistant to the village mill-wright and blacksmith, or as an employe of the woollen, grist or lumber mill of his locality. He has, of course, the opportunity—if he knows about it—to contribute to one of the correspondence schools and by the amount of money he sends out of the country, prove his earnestness to educate himself.

The wealth of the world is a universal fund from which every individual has a right to acquire a share. Some acquire much more than others, but not always by ways or in a manner which commends itself most highly to those who are desirous of seeing the best influences dominating. The greater number who observe purer ethical guidance are generally insufficiently prepared to hold their place in this crush for a share of the fund.



J. P. Murray

The race is to ability and endurance, if equal conditions allow all to compete, but many, having this equal right to enter, and who could win wealth and renown, are handicapped by customs established for years.

Custom, however, should not be considered as a finality. From the beginning it has yielded to improvement and in no sphere of our environment should it more easily be forced to yield, than when the nation's source of progress is clogged, and the necessary freedom in opportunity is supplied, for producers to equal, if not to surpass, their competitors of other lands.

At present Canada is proud of her Conservation Commission looking to the care of our national resources. Have we a greater or more valuable resource than our boys, and, are they not worth spending money on?

It may then be permitted to submit for consideration a suggestion, which if tried, would open up new ideas, give to the country-boy a wider sphere for his ambition; give the University, through the advanced student or post graduate, an opportunity of getting into close touch with actual practical machinerp and materials, doing commercial work. It would let the advanced workman in the workshop rub shoulders with the student workman, who hopes to be a more advanced workman. It would give entertainment in towns and other places where amusements are lacking. Entertainment is restful and entertainments may be instructive. It is not difficult to surmise that from the experience gained, present University theories having been applied to practical work will be found to require considerable modifications and by the necessarily inductive reasoning by the graduate, and the University, better methods would suggest themselves and very much better results obtained.

The suggestion above referred to, is for a system to be planned by which advanced students, graduates or post graduates may be organized into an institution which will supply scientific lecturers to small towns who are not able to undertake the heavy charge of technical education.

These traveling lecturers would be sent throughout the province, during recess time, from May until October, and would be better for the workshop employes than the most complete correspondence system. For the student or graduate, the association with practical work would induce investigation and deeper research and this would develop practical results from abstract thinking.

The question may properly be now asked how is this to be made feasible? In answer, it may be said, that but four things are required, three of which are now available. They are: the traveling lecturer, the buildings in which to lecture, the practical industry, and the one to be supplied, the expenses.

The first we have in the number of University students who probably would be glad to avail themselves of such an opportunity to improve by teaching and practice, advance their position and also acquire a considerable amount of valuable information for themselves and the University. They would be able to do this at no cost to themselves but would be quite a little ahead when their season was over.

The second, the buildings in which to lecture, are already built and in waiting. The schoolhouse of every hamlet, village or town stands closed from early in the afternoon until class hour next morning; closed when it might be profitably used by workmen of the local industries; where the traveling library may be housed during its time in that district; and where the travel-

ing lecturer may gather around him in the evening the boys and workmen. The following day, while the school is being used for its original purpose, the traveling lecturer would be in the factory or mill, aiding where his knowledge is available and on his part, learning from the actual doing and testing the empirical effort of the college laboratory.

The next item—the practical industry.

No need to point them out as every place which has a schoolhouse has a local industry or two.

The last is necessary to the success of the whole.

This sum required would be so small in comparison with the benefits to be derived, that it could hardly be imagined that a government with the desire to advance technical education would hold its consent. Estimate, say, fifty students, for six months, covering traveling expenses and an honorarium. There should be little hesitation in finding the very small sum which such a very great desideratum would cost.

The technical education of the country-boy, the improvement of the country-workman and the better qualifying of the graduate are not the only benefits to be derived from this suggestion if made operative.

One of the grave problems of the day is, to keep the youth of the country, in the country, near the land and not let him drift into the city. And properly so. City life has many alurements for inexperienced youth and too often it has been the undoing and ruin of many who would have developed into men of great mark had they not been taken in their tender years from their country home.

The boy coming to the city for his education may be said to be lost forever to his home. But can he be blamed for having an ambition to do better than country life offers to-day? He has no chance to select a vocation nor to discern his ability. So, at considerable cost, both of heart and money, he leaves his childhood home to try to win in the throng and bustle of city life, that will-o-the-wisp, "success," away from parent and pastor, both of whom would keep him good but——.

The one great lever which can raise all workmen to the same platform, giving to each an equal opportunity, is education. It will lift the workman's possibilities and aided by an unrestricted freedom for the honest effort of properly trained ability, will make him the co-equal of any. And, as the children of the State are all equally subject to acknowledged authority, so should this governing authority recognize this right for an equal treatment of the children.

The foregoing thoughts are but one phase of a subject which gives many, sides, any one of which might well deserve a very careful study by our universities. The present method of education, and the freedom of franchise, suggest the supplying of children's clothes for the adult and stuffing the child with man's food.

Mr. P. W. Ellis saw the future of Canada. He referred to the great part the university was playing in the country's development. He made special reference to the scientific uses of the waters of Niagara Falls and the water powers of Ontario in the development of electricity as a substitute for coal.

"The Engineering Profession" was presented by R. H. Johnson and responded to briefly by W. J. Blair, a graduate of the School, now Mayor of New Liskeard, and Dean Galbraith.

During the evening special selections were rendered by the Science Octette, consisting of J. G. McKinnon, H. Stuart, J. L. G. Stewart, C. B. Ferris, W. C. Blackwood, A. A. Kinghorn, J. H. Craig, R. B. Chandler; Mr. C. Bush was conductor.

The entire executive deserve the greatest credit for the able management which brought the dinner to such a successful issue; also Prof. Wright, whose assistance in all such events is almost invaluable.

THE BEGINNING OF ELECTROCHEMISTRY.*

SAUL DUSHMAN, M.A.

The last quarter of the eighteenth century saw an immense transformation in chemical science. Lavoisier, the great French chemist, had by a series of masterly investigations established the Law of Conservation of Mass as a fundamental principle of the science. "Nothing is created, either in the operations of art, or in those of nature; and one may lay down the principle that in every operation there is an equal quantity of matter before and after the process, that the quality and the quantity of the principles are the same, and that there is nothing but certain changes, certain modifications." These are Lavoisier's words. In the face of rapidly accumulating facts, the old phlogiston theory with its constantly varying conceptions had to recede and finally vanish, while in its place arose the new chemistry based on the study of the **quantitative** relations between the substances taking part in chemical reactions. It was recognized that certain substances are definite, distinct and homogeneous, and the object of chemistry was declared to be the investigation of the ultimate components which constitute the different substances found in nature.

Chemistry was thus in a position to interpret the new scientific discoveries which were made about the end of the eighteenth and beginning of the nineteenth centuries, discoveries were not only to profoundly affect the history of chemistry itself, but to lead to the development of a new branch of science, that of dynamic electricity.

From the sixth century before the present era, when it was accidentally discovered that rubbing amber causes it to attract light bodies, to the year 1789, electricity had not made any great progress. During the eighteenth century there had been a gradual evolution in machines for the production of so-called

*In connection with the preparation of this brief sketch, I have made free use of Ostwald's Geschichte der Elektrochemie as well as of Pattison Muir's History of Chemical Theories and Laws.

static electricity, and physicists in general attempted to rival each other in the size of machine they could build or the length of spark that these machines could produce. Theories and hypotheses were, of course, not lacking. Some crude instruments for quantitative investigations had been devised and the main facts known at that time could be summed up in a few generalizations, the most important of these being Coulomb's laws governing the attraction and repulsion between two electrically charged bodies.

Galvanism.

During the last decade, however, of the eighteenth century certain discoveries were made which gave a new trend to the study of both electricity and chemistry. In 1791, A. Galvani, a physician of Bologne, published a small volume containing a

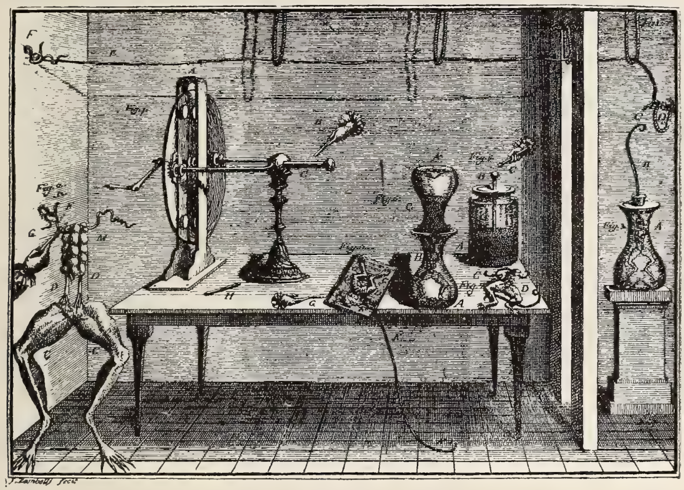


Fig. 1

description of certain new phenomena which had been observed by him. He writes as follows:

"The matter began in this way: I dissected a frog and prepared it in the manner shown in Fig. 1 (left-hand side of diagram); then, while intent on some other matter, I laid it down on a table on which stood an electrical machine. . . . Now as one of the assistants happened to touch the nerves, DD, with his scalpel, all the muscles appeared to contract as if afflicted with heavy cramps. The other assistant believed, however, that the contractions occurred at the same time as sparks were drawn from the machine. Astounded at this new phenomenon, he drew my attention to it, for I was engaged quite otherwise and was engrossed in meditation. Thereupon I became possessed of an incredible eagerness and desire to inquire into this phenomenon and to bring to light whatever might be hidden

therein. I, myself, therefore touched one or other of the nerves with the tip of the knife, and, at the same time one of the assistants drew sparks from the machine. The phenomenon appeared again as before."

After describing a number of other experiments, Galvani goes to to state that contractions were also obtained without the use of the electrical machine, by touching with a metallic connector the muscles of the leg and the copper hook on which the specimen was suspended. (This is illustrated in Fig. 2.) With a connector consisting of some non-conducting material the contractions did not appear. The same muscular motions were observed when the specimen was laid down on a metal

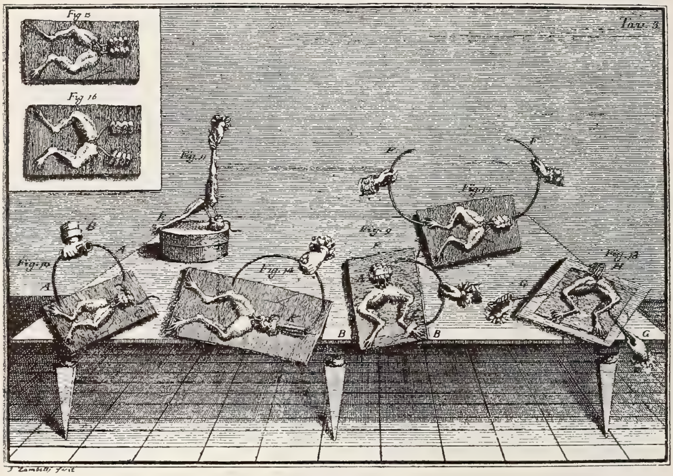


Fig. 2

plate. But the peculiar circumstances noted in all these experiments was that the contractions were much more violent when the connection between nerve and muscles was made by means of two different metals. "Thus, when the connector, the hook and the metal plate are all of iron, it often happens that the motions cease completely or become extremely weak. If, however, one of the above articles is of copper or silver, the contractions are much greater and last longer."

How explain these phenomena? "From what has been investigated and is known, I believe that it is evident that animals possess a peculiar electricity of their own. . . It is distributed throughout all the organs and parts of every animal, but is best exhibited by nerves and muscles. The peculiar and previously unknown property of this kind of electricity is that it passes from muscles to nerves, or rather from the latter to the former." That is, the nerve and muscle bear the same relation to each other as the coatings of a charged Leyden jar; by connecting the

nerve and muscle through a metallic conductor, a discharge occurs just as in the case of the latter. Of course, the implicit assumption in this explanation was that the electric charges are already present in the animal. Such an assumption, as has been pointed out by Ostwald, was quite natural; but wherein Galvani made the mistake was in not stating that it was an hypothesis, which therefore ought to be confirmed or disproved by separate experiments.

Volta's Investigations.

It is therefore not surprising that another explanation soon appeared which transferred the phenomenon of Galvanism from the realm of physiology to that of physics. Volta, a distinguished Italian physicist, directed his attention to the fact which had been neglected by Galvani; namely, that the contractions were

Fig. 3. A. Volta

much more violent when two different metals were used as "discharge conductors." From this he was gradually led to the conclusion that in Galvani's experiments the frog's legs play a double function: one, as a sensitive electroscope or electrometer* and the other, as an actual-generator of electricity. The manner in which Volta arrived at this conception is evident from the communications which he addressed at various times between 1792 and 1796 to different scientific journals. In a "preliminary communication" of 1792, he describes how electrical phenomena may be exhibited by interposing a moist conductor between two different metals. In a later communication, we find the first mention of the voltage series. After

*The electroscope or electrometer, as devised by Bennett, 1786, consists of two gold leaves suspended in a glass case. The leaves are connected to a metal cap on top of the case; by bringing any charged body in contact with this cap the gold leaves are made to diverge.

again asserting that the motions of the frog's legs are due to the production of electricity by the contact of two different metals, he mentions that by placing one metal in contact with the tip of the tongue, and the other metal in contact with its lower edge, a peculiar sensation of taste or light is produced when the free ends of the metals are made to touch; "and these sensations and motions are stronger, the further apart the metals are in the following series: zinc, tin-foil, ordinary tin, lead, iron, brass and bronzes, copper, platinum, gold, silver, mercury, and graphite." Later on he gives a more systematic statement of his theory. "The contact of different metals (conductors of the first-class) with other liquid conductors (those of the second class) excites and disturbs the electrical fluid and gives it a certain impulse. Do not ask me the reason for this; it is enough that it is fact, and a general one at that. This impulse, whether it be one of attraction, repulsion, or some other kind, is different and unequal for various metals and liquids. . . You now see wherein the whole secret, the whole magic of galvanism consists. It is no more than an artificial electricity set in motion by the contact of heterogeneous conductors. It is these different conductors that are the real source of the electricity, and this law holds not only for metals or conductors of the first class, as one might have believed, but also more or less for all conductors, according as they are more or less different in nature. . . As long as you proceed from these laws you will be enabled to explain all the observations made hitherto, without having to trust to any assumption as to the existence of an active animal electricity. If, however, you abandon these fundamental laws, you will meet in this extensive realm of experiments with nothing else but uncertainties, anomalies, and contradictions without end, and everything will become for you an insolvable riddle." Comment is hardly necessary!

In answer to the question as to whether the electricity had its origin at the contact of the two metals or at the contact between metal and liquid, Volta referred to his experiments with the electroscope. As he had observed that the mere contact of two different metals was sufficient to produce an electric charge on each, he concluded that the electricity was always produced at the contact of the metals. "Herein, as we shall see, lay one of the most fruitful mistakes in electrochemistry."

A most important advance was made by Volta in the invention of his battery. A description of this is contained in a letter to Sir Joseph Banks, president of the Royal Society of England. As shown in Fig. 4, it consisted of pieces of silver and zinc arranged alternately and separated by layers of moistened cloth or leather. The apparatus was found capable of producing shocks comparable in magnitude with those of a Leyden jar. What was still more wonderful, it gave a continuous discharge, "without the aid of any external means of renewing the electric charges!" It was observed that the electrical effects

of the battery increased with the number of pairs of plates in series, and Volta gives an experiment illustrating this. A battery was made by arranging in order sixty beakers, each containing a zinc and silver plate in salt solution. In the first twenty, the silver plate of one beaker was connected in series with the zinc of the next, in the second twenty the order of the plates was reversed, while in the remainder the plates were arranged in the same order as in the first set. "Now dip one finger in the water of the first beaker and then, by means of a plate held in the other hand, touch in succession the connectors between the different beakers. . . You will begin to feel a slight stimulus in the fingers when you have reached the fourth or fifth beaker, and as you pass on to the sixth, seventh, and so forth, the shocks will become greater until you reach the twentieth; then as you pass on to the twenty-first, twenty-second,

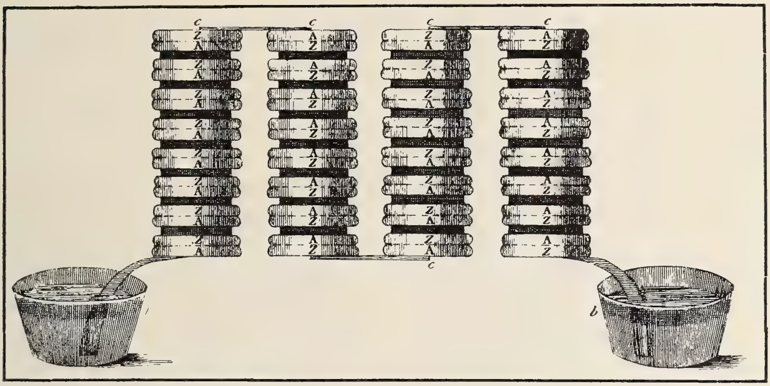


Fig. 4

and twenty-third, the shocks diminish in intensity and gradually become weaker until at the thirty-sixth they are scarcely perceptible and are completely absent at the fortieth. When you have passed this . . . there will be no noticeable stimulus until you reach the forty-fourth or forty-fifth; from then on the shocks continue to increase until the end of the series, when they are as intense as those obtained with the first twenty." The noteworthy feature in this is the demonstration that by means of an arrangement such as the above it is possible to obtain a **graded summation** of the electrical effect or **tension** produced by one pair of plates and a liquid conductor, and that these tensions may be added or subtracted by arranging the plates in different ways.

Decomposition of Water.

Undoubtedly Volta must have noticed some chemical changes in the zinc plates, and in some of his experiments there

must have been an intense evolution of gas due to the decomposition of the water. Yet he makes no mention of any such observations. As Ostwald states, he had his theory of contact electricity already evolved before the fact was brought to his attention that chemical reactions in the cell are the necessary accompaniment of the electric current produced by it. Volta actually believed that his battery was a perpetual motion machine, and refused to recognize that the relation between chemical action in the cell and the galvanic current is the same as that between cause and effect. For a long time this oversight on the part of Volta greatly hindered the advance of electrochemistry, and even at the present time, the ideas taught by his school have not been completely eradicated.

As soon as the communication from Volta reached London, and even before it was published, knowledge of its contents spread amongst the physicists there. Two of these, Nicholson and Carlisle, immediately set about repeating Volta's experiments, and it is a curious fact that one of the first discoveries made by them was the chemical action of the galvanic current. On connecting the end plates of the battery to two brass wires under water they observed that the wire connected to the silver plate was oxidized, while hydrogen gas was evolved at the other. At platinum wires, oxygen and hydrogen gases were formed in about the proportion of one to two volumes, and the conclusion was therefore drawn that the water was decomposed by the cement into its constituents. Nicholson and Carlisle also noticed that acids were produced at the same wire as oxygen, and alkalies at the other wire.

Before proceeding with an account of the many investigations so brilliantly initiated by the work of these two experimenters, it is necessary to remark that although they were the first to decompose water by the galvanic current and to obtain oxygen and hydrogen separately, yet the existence of a relation between electricity and chemical reactions was by no means a new observation. In the middle of the eighteenth century Beccaria succeeded in reducing various metallic oxides by subjecting them to the action of an electrical machine. Priestley noted that an acid is formed by passing spark discharges through air over water and assumed the compound to be carbonic acid, but Cavendish recognized it as nitric acid. Van Marum repeated Priestley's and Beccaria's experiments and observed that the electric spark produced not only reduction of oxides but also, under other conditions, oxidation of metals. Finally, in 1789, Deimann and Paets van Troostwyk decomposed water by means of the electric discharge.

Immediately after the publication by Nicholson and Carlisle of their results, and in the same year, Cruikshank succeeded in decomposing various metallic salts such as copper sulphate and silver nitrate and observed that the metals were liberated at the same wire as hydrogen (in the decomposition of water).

The interest aroused by these discoveries was very great. Everybody who could afford a few silver coins now made a Voltaic battery and tried experiments on the decomposition of all kinds of substances; in consequence the scientific journals were filled with records of many so-called discoveries, most of these, naturally, being more or less imaginary.

One of the very few who investigated these phenomena with real scientific acumen, was Sir Humphry Davy, the director of the Pneumatic Institute. From the first he was led to favor the "chemical theory" of the Voltaic cell as contrasted with the "contact theory" of Volta and his adherents. In this he was influenced by the observation that the power of the battery to decompose water and to produce shocks increased in the same proportion as the rate at which the zinc was oxidized. But it was mainly through two investigations, published be-

Fig. 5. Sir Humphry Davy

tween 1806 and 1807, that Davy attained an international reputation. The first of these dealt with the anomalous production of acids and alkalies in the decomposition of "pure" water. Davy showed that this phenomenon was due to impurities produced by the solvent action of the water on the containing vessels, and that when care was taken to obtain absolutely pure water there were formed no other products but oxygen and hydrogen. The second investigation resulted in the preparation of the metals potassium and sodium from their fused hydrates (which had previously been thought to be elements) by the agency of the electric current. In 1808 the metals of the alkaline earths were similarly obtained.

Not content with merely giving an account of his results, Davy also formulated an hypothesis by which he attempted to

connect positive and negative electricity with the chemical reactions between different substances. His suggestions were later adopted by Berzelius in his famous electrochemical theory. It would be going beyond the scope of the present article to discuss, even briefly, Berzelius' views which were, after all, of much greater importance to purely chemical speculation than to electrochemistry. The electrochemical investigations carried out by Berzelius and Hisinger (1806) were of fundamental importance for the development of this theory. Since in the decomposition, by the galvanic current, of the salts of the alkalies and alkaline earths (the only compounds investigated by them) acids and alkalies are produced, Berzelius concluded that all salts are decomposed by the current into acids and alkalies. Thus potassium sulphate (K_2SO_4) was assumed to decompose into K_2O and SO_3. In the case of chlorides he believed at first that chlorine is an oxide of some unknown element and was convinced of his error only after a great many years. Probably if he had begun his researches with the metallic salts his views on chemistry would have been radically different; but as it was, his speculations influenced chemical theory for a long time and thus partly offset the services rendered to the science by his many important discoveries.

Physical Conceptions.

While the invention of the Voltaic battery thus led to the development of a new and extensive application of the galvanic current to chemical reactions, the more purely physical conceptions of potential, current-strength, conductance, and resistance also became gradually defined, and since these terms and the ideas involved in them are of extremely great importance in the history of electrochemistry a few remarks on this subject will not be out of place.

The first experiments with electrical machines led physicists to perceive that various charged bodies produced shocks of greater or less effect when brought into contact with the human body. This was expressed by saying that the electricity present in that body which produced the most painful effect possessed a much greater **intensity.** The next advance was made by means of the electroscope; it was noticed that the more intense the physiological effect, the greater the degree of divergence of the gold leaves, and since a physiological effect is more or less a question of personal temperament, it became customary to define intensity by the degree of divergence observed in the electroscope leaves.

It is worth noting that in the conception of **temperature** there was a similar development. At first, bodies were classified as hot, cold and so forth; but when it was perceived that a column of mercury in a glass tube increased in volume as the degree of hotness of the body with which it was placed in con-

tact, the change in volume of the mercury was defined to be a measure of the temperature, or degree of hotness.

About 1782 Volta expressed himself as follows; "By **intensity** I understand the **tendency** with which the electricity strives to escape from all parts of an electrified body; to which tendency correspond the electrical phenomena of attraction, repulsion, and especially the degree of divergence of an electroscope." The same idea was applied to the Voltaic cell; the electric charge on the zinc possesses a different intensity to that on the silver; on interposing a conducting medium a discharge occurs from one to the other. We have previously given an account of Volta's experiment with the battery of sixty cells; from this he concluded that the **differences in intensity** between zinc and silver may be added or subtracted; that is, they possess not only a **definite magnitude** for each pair of plates, but also a **fixed polarity.**

Volta's Potential Series.

Volta now began an investigation in which differences in intensity of various galvanic combinations were measured by means of a modified form of electroscope. The divergence in the gold leaves produced by a zinc and silver plate was **measured.** "Other metals when brought into contact produce a **difference in intensity** which decreases with the difference in the power of exciting electricity and is less the nearer they are to each other in the following series: silver, copper, iron, tin, lead, and zinc, in which order the electric fluid is always impelled from the preceding one to that following."*

By placing two or more zinc-silver cells in series the divergence of the leaves was increased proportionately. Various combinations of plates were then tried, and it was observed that the **difference in intensity between any two metals in the above series is equal to the sum of the differences between those intermediate.** As Volta says: Assume that silver impels the electric fluid to copper with a force 1, copper to iron with force 2, iron to tin with force 3, tin to lead with force 1, and lead to zinc with force 5, then the difference in intensity (or **potential,** as we designate it at present) between silver and zinc is equal to 12.

It was subsequently shown by Pfaff (1808) that the above order of the metals varies with the nature of the intermediate liquid. The difference in intensity of the plates in a galvanic cell thus came to be considered as a distinct property of depending upon the nature of the metals used and the solution, but **independent** of the area of the plates or size of cell. Since this difference in intensity is what causes the electricity to flow through

*The tests with the electroscope showed that the zinc was positively charged with respect to the silver, hence it was concluded that the positive current flowed from the silver to the zinc (outside the cell).

a closed circuit, this was gradually replaced, as far as galvanic cells are concerned, by the term **electromotive force.**

Very early, however, it was recognized that the rate at which a battery produces chemical decomposition or the rate at which the zinc plates are oxidized, varies according to the substances which are connected to the terminals of the battery. Here then we have the necessity of bringing in the ideas of **conductance and resistance**; certain substances resist the flow of the electric current, so that less electricity is transferred in a given time, other substances permit a large amount of electricity to pass through in the same time. The notion

Fig. 6. Michael Faraday

that rate of chemical decomposition and rate of flow of electricity are proportional was also vaguely present in men's minds. It remained, however, for Faraday to demonstrate conclusively that such a relation exists.

In 1820, Oersted discovered the action of the electric current on a magnetic needle; then followed in rapid succession the invention of the multiplicator and the compensated galvanometer of Nobili. Of very great significance for the development of electrochemistry was the deduction by Ohm, of his well-known law (1826) connecting potential difference, current strength, and

resistance. Through the masterly investigations of Fechner this led to a much more accurate definition of electrical units.

With the evolution of these quantitative methods of investigation, electrochemistry was established on a firm foundation; but it took many years before the struggle between the chemical and contact theories came to an end in the complete overthrow of the latter. The story of this long and useless debate extending over half a century is neither interesting nor profitable, so that here our sketch of the beginning of electrochemistry must close. To attempt to recount the developments in this subject since the time of Faraday would be equivalent to undertaking to write a treatise on electrochemistry, an intention which the writer does not possess.

NOTES ON PIPING SYSTEMS FOR STEAM POWER PLANTS.

A. G. CHRISTIE, '01
Steam Engineering Department, University of Wisconsin

As soon as the size and number of the engines have been decided upon, the next step in the design of a steam power plant should be to lay out diagrams of the complete piping system. From these diagrams not only can the relative location of the different machines be settled, but the form and character of the building itself will also be settled to a certain extent.

The piping system selected must provide for repairs while the plant is in operation. If the plant is to run continuously, the system must be so arranged that sections can be cut out for repairs. If, however, the plant only runs for a few hours a day or if only for a very short period, flexibility of the piping system is not essential.

Few designing engineers seem to realize the necessity of complete and well thought out diagrams of every pipe system in the station. The erection cost of the plant will be greatly reduced where the designs cover every detail even to drip lines, especially where the piping is installed under contract. Delays in getting under way and the annoyance and trouble of finishing up details by the operating force, are avoided where the piping is installed complete. The writer recalls one plant where the small details were overlooked and which were installed by the local force. The cost of material and labor to finish these parts amounted to nearly half of the contract price of the main systems.

Poorly designed pipe lines which are always giving trouble have a demoralizing effect on the operating force. These men as a rule take a deep interest in their plant if it can be kept in good shape, but soon get disheartened and discouraged when they have to stay after hours and work under difficulties over a hot boiler repairing some leaky steam line only to find the next

day that there is trouble with some other portion. Many of these difficulties would be overcome and many mistakes avoided by careful consideration of piping diagrams before the plant is designed.

The first point to be decided is the selection of the system for the main steam piping. This in many instances consists of a long pipe into one end of which the boilers deliver steam while the engines are connected to the other end. This system is probably the worst that could be selected, for should any trouble occur on this pipe, there is no chance to repair it, for as a rule no valves are provided to divide the line into sections. Fortunately, however, few modern plants are designed with this system.

A few years ago, loop systems were used to some extent. However, these necessitate considerable first cost and the condensation losses have been found to be very high. The system, while providing for every contingency on paper, is apt to have too many valves and in the excitement during some trouble the operator is sure to open or shut the wrong valve.

Another system similar to the previous one is the duplicate main. This system is very costly to install, has high radiation losses, has a great number of valves, usually involves considerable repair work to keep joints tight and if one line is dead, it is subject to expansion and contraction troubles. As a whole it is not as satisfactory a system as the loop system.

In large plants, the unit system is principally used. This consists of an engine piped direct to its own set of boilers. The piping is thus very simple as each engine and boiler form an elementary power plant by itself. Sometimes each unit has its own set of auxiliaries, although in general, the complete station auxiliaries are grouped and form a system by themselves. The steam lines of the various units of the plant are connected to each other by cross connections so that one unit can help out another in emergencies.

For smaller plants this system may be modified by placing the boilers and engines back to back with a division wall between. The main steam line which is usually on the boiler room side, is divided by valves into sections so that each section connects with one or more boilers and supplies one or possibly two engines. By working over the diagram it will usually be found possible to cut out one section for repairs and still be able to operate the greater portion of the plant. This reduction of plant capacity is one of the chief objections to this system. Its chief advantage lies in reduced first cost, its simplicity and the small number of joints, and hence small repair bills if well put up. The last system is now used very extensively and in general gives good satisfaction when the piping and valves are of good material and well put up. Freedom from complexity should be aimed at in every case for it seems to be almost always the case that trouble occurs at such a time that the cool-headed engineer

is not on the spot. Then the simpler the system, the less chance for the excited fireman to open or close the wrong valve.

Probably the final selection of a system will be made on the basis of cost. But it is well to remember that the safety of life and property are dependent on good reliable pipes and fittings and for this reason alone besides that of reliability of operation, repair bills, etc., it is always desirable to install high-grade piping systems.

Next comes the selection of a system of steam piping for auxiliaries. In plants of small capacity the auxiliaries take steam from the main line. In large plants they are usually provided with a system of their own. The auxiliaries, which are usually, comparatively speaking, cheap machines, do not operate satisfactorily on superheated steam and consequently are usually supplied with saturated steam from the boiler drums by a pipe system of their own. In some states such a system is insisted on by the boiler inspectors and underwriters so that failure of the main steam line, or a shut down for repairs, does not cut steam off the boiler feed pumps, the fire pump and the exciter. The safety of the boilers in case of trouble is largely dependent on the boiler feed pump in order to prevent low water troubles. The fire pump must always have steam. The power plant itself should be lighted by the exciters and under no circumstances should it be allowed to be in darkness. In case forced or induced draft is used, the engines driving the fans should be included with the above unit.

These auxiliaries should be in duplicate and so located, and the auxiliary steam line so designed that continuity of operation is assured. It is advisable to have these near the centre of the boiler plant so that the auxiliary main can be divided into sections.

The feed water piping is usually installed with a system of duplicate mains, with separate connections to pumps and boilers. As a rule these are the only pipe systems to which much attention is given in the boiler room. But the systems for auxiliary exhaust steam, for heaters and economizers, for blow-off pipes, for drains and sewers, for drips from main steam lines, from auxiliary lines and from the boilers themselves, should be gone over individually and a system selected. No general statements can be made regarding these for, as a rule, they are largely dependent on local conditions of the plant being designed. However, in the design of the station each of these systems should be worked out carefully.

After the whole plant has been worked over diagramatically, then the machinery can be located, floor and building plans drawn and piping drawings can also be made. The piping drawings will show the sizes of pipes and the location of pipe lines relative to the building, to boilers and to other fixed machines. All the pipe systems should be drawn out so that there may be no interference of different pipe lines. Alterations of the original

systems may have to be made so that the pipe lines may be accessible for operation aand repairs. The location of valves and traps should receive most careful consideration for very often these are located in places, which if not inaccessible in a hurry, at least are not easily got at and hence are often neglected and allowed to get out of order. Galleries should be provided along the main steam header for use in operation and repairs. The most suitable radius of each bend should be determined and placed on the drawings.

Almost all large piping jobs are done by contract, by one of the large pipe concerns. If it is intended to let such a contract for the plant being designed, it is not advisable to detail the piping as the contractor has designers who can do this to the best advantage as they know the standard sizes of their fittings and their methods of cutting and assembling pipe.

After the location drawings are made, as just outlined, the specifications for the piping, fittings, valves, separators, traps, pipe coverings, etc., can be prepared and the pipe contractor required to submit detailed drawings with his bids. If, however, the piping is to be done by some local concern or by pipe fitters employed by the company for whom the designs are made, then detail drawings of the complete plant should be prepared.

One point which must be kept in mind in laying out all piping, is to allow for expansion. The writer recalls a plant with 30 feet of horizontal exhaust piping and no allowance for expansion at either end. Considerable money was spent to change the footings under the condenser so that it could move on rollers. An expansion joint was out of question on account of the size and cost. It is often advisable with steam mains to have the pipe cut so that when anchored in the middle the ends will be in correct position only after expansion under operating conditions. In erecting, the pipe connections to engines and boilers may have to be sprung into place but will correct themselves when heated up.

In considering the details of the different systems, those connected with the main steam pipe should receive close attention. The main steam pipes may be either of wrought iron or steel. The latter is now generally used and for best service should be standard weight lap-welded Openhearth steel up to 125 lbs. dry steam if threaded, and up to 200 lbs. when welded flanges or "Van Stone" joints are used. Above these pressures use extra heavy pipe. When superheat is used, it is advisable to avoid all threaded joints as they are subject to leakage troubles.

Formerly all flanges were of cast iron. Practice now seems to favor steel flanges in every case above 3 inches as they are less liable to break in tightening up over gaskets. Where ground joints are used, no gasket is necessary and the joints are simply painted with raw linseed oil while being assembled. With other classes of joints gaskets are required. The flanges may

be turned flush or may be made male and female. The latter have one advantage in that the gasket is not liable to blow out, but this form of joint is very hard to repair.

For gasket material, rubber and vulcanite compositions are suitable for wet steam up to 100 lbs. For higher pressures and for superheated steam wire-woven asbestos, corrugated copper, soft sweedish iron, smooth-on, and other metallic gaskets may be used. When high superheat is used, great care must be taken when laying out steam lines, to see that repairs to gaskets can be readily made for repairs will be surely needed. Copper gaskets should not be used with superheat as they usually fail due to pitting. The life of a gasket will largely depend on the care exercised in fitting up the joint. It should be drawn up evenly all around and not strained and flattened on one side. The life also depends on the proper drainage of the steam line, for condensation lying to some depth on one side of a pipe invariably starts a leak in the gaskets.

Gate valves are used for dividing the main into sections and for steam connections from the boilers and to the engines. These having outside nickel steel stems are preferable as they give an indication of the position of the valve inside. The bobies may be of well selected iron with heavy ribbed walls so as to avoid distortion of the valve faces. Since cast iron is not considered by many engineers as suitable for superheat, valves are being made of semi-steel and even of cast steel. These give excellent service but are expensive. The discs and seats of these valves should be of high-grade cast iron or of nickel steel. The use of brass or bronze seats should be avoided with superheat as electrolytic actions are frequently set up with the iron in the bodies. Globe valves are seldom used except as engine throttles The valves on the boiler connections should be located at the highest point so as to avoid pockets to collect condensation. One of these valves should be an automatic non-return valve.

It is not intended to discuss the sizes of pipe for mains, etc. Since velocity losses are reduced by superheating, smaller sized pipes can be used and thus radiation losses are reduced. The pipe size may also be reduced when steam turbines, taking a steady supply of steam, are connected to the line. In fact, the real criterion for pipe size, is to make the sum of velocity losses and radiation losses a minimum.

Fittings are usually made of cast iron. More recent installations have used cast steel fittings and in some cases have done away wth fittings altogether and have welded flanged nozzles for branches on to the pipe itself. This is a decided advantage for less joints are used and hence less places to repair. The pipe line is also of homogeneous material.

When fittings are used, care should be taken to avoid the formation of pockets as the collection of water in these is a source of trouble. Those fittings should have long fillets whose branches or flanges are cast on so as to minimize casting strains.

Wherever possible it is advisable to use bends of long radius in place of elbows. The number of joints is reduced, the drop in pressure is also reduced and expansion takes care of tself.

Provision should be made to anchor the main steam pipe at one point, preferably the middle in pipes of moderate length. Saddles through which the pipe can expand should be provided at intervals. If the pipe is long U bends may have to be provided in the central portion. Sliding expansion joints should never be used when bends can be installed.

All steam lines should be amply provided with drains leading to traps. The piping for these should be carefully laid out and also the piping for the disposal of the trap discharges should be shown. If the plant is large enough to warrant the expense the discharges may be led to a receiver from which a small pump forces it into the boilers. Otherwise the trap discharges should be piped to the heaters where the hot condensed steam has a decided value.

In piping up drips, drain lines and other small piping it has been found that a cheaper and more satisfactory job is obtained by using bent pipe with couplings in place of regular fittings whenever this is feasible. Pipe fitters soon learn to do rapid and neat bending and soon prefer it to fittings. The finished job presents a neater appearance and by the elimination of joints, it lasts longer and requires less repairs.

All piping carrying live steam should be well covered with a suitable heat insulating material, as the radiation loss is a fixed quantity depending on the temperature of the steam aand efficiency of the pipe covering. The very best covering for the conditions, should be purchased. Also all fittings, flanges, valves, drip lines, traps, etc., should be amply covered and the saving will pay high interest on the cost of covering.

Connections to engines should be taken off the top of the header to provide as dry steam as possible. A valve should be provided at this point so that repairs can be made on this piping. Here again long radius bends should be used in preference to elbows. A separator or receiver is usually placed before the throttle valve to insure dry steam and in reciprocating engines to provide a large supply of steam close to the engine and thus reduce the drop in admission pressure in the engine. Auxiliary steam lines in general have practically the same equipment as the main steam lines. The main point to watch in the design is to provide connections so that in any emergency, it is still possible to keep the boiler feed pumps going.

Exhaust lines are usually of cast iron or riveted steel. When high vacuum is desired tight exhaust lines are absolutely essential. Air leakage of cast iron piping is rather an indefinite quantity and requires some investigation. The chief sources of leakage are chaplets for holding cores, porous castings and blowholes, and joints. The gaskets should all be tightened up after

the pipe is hot and the pipe lines should be painted under vacuum with heavy asphatum paint.

The location of exhaust pipes is largely determined by the local conditions. The connections to the condenser should be as short and direct as possible. All valves should be heavy gate valves. An atmospheric exhaust pipe and automatic relief valve must also be provided.

Proper allowance must also be made for the expansion of this pipe either by providing large copper expansion joints or by placing the condenser on rollers.

The boiler feed piping should always be in duplicate so that a failure of one pipe does not endanger the boiler. The spare feed line when not used for boiler feeding purposes can be supplied with city water or water from a service pump to run boiler tube cleaners, to wet down ashes, to wash floors, for toilet purposes, for water-cooled bearings, etc.

The feed pipes should also be provided with bends in place of elbows to reduce vibration in the piping. Screwed flanges can be used with rubber composition gaskets. The piping may be of brass or steel and should be made heavy as it is often called on to withstand high pressures owing to racing of the pump. The feed valves to the boilers as a rule are globe valves which permit close adjustment of the feed. The connection into the boiler should be provided with a check valve to prevent the return of the hot water from the boiler into the feed lines in case of accident.

As these pipes carry hot water, they should be very carefully covered with heat insulating material. This is especially necessary where economizers are used.

The boiler feed pumps must be in duplicate and should be fitted with a good type of pump governor. Heaters for the feed water should be provided to utilize the heat in the exhaust steam from non-condensing auxiliaries.

Another pipe line deserving close attention is the blow-off pipe. The expansion of this line at each blowing-off of the boilers must be taken into consideration and provided for. Otherwise trouble will be experienced with the blow-off connections to the boilers. This pipe should not be discharged into a sewer or other conduit as the scouring action of the hot water and steam is very distructive. It should be led into a basin into which it can discharge and from which the steam produced can escape by suitable vents. Blow-off pipes are often placed under the floor or in a trench where it is impossible to get at the joints to make repairs. This should be especially avoided. Sometimes connections and valves are provided to the boiler feed pumps and the boilers can be supplied with water from this source in emergencies.

Each blow-off connection to a boiler should be provided with a high-grade blow-off valve and with either a gate valve of a heavy plug cock. This adds security and enables the blow-

off valves to be frequently inspected and kept in good repair.

Some stations are provided with oiling systems. These are determined largely by the class of engines installed, by the type of oil filters and by the local design of the station. Hence no general discussion of systems will be given.

In conclusion then for economical first cost, considering operating costs, the piping systems must be simple, flexible and accessible, the pipe lines must be of first-class material well erected, every square inch of radiating surface of high pressure steam piping and feed piping must be well covered with the best of heat insulating materials, accessibility for making repairs must be kept in mind, and all small pipe systems should receive consideration in the designs.

GAS ENGINES.*

NORMAN C. SHERMAN

Gentlemen,—It is with a good deal of trepidation that I appear before you, knowing that there are probably some men present to whom my remarks may be history and to a large number I may appear to have merely touched the surface.

However, the subject is a very comprehensive one and I can only hope to bring before you some of its outstanding features.

I have chosen to call the gas engine a development of the steam engine. In burning coal for the generation of steam there is a continual escape of heat by reason of the imperfections of the furnace, and by the discharge of heated gas up the chimney. Also there is some difficulty in forcing the heat through the shell of the boiler and conveying it to the particles of water to form steam.

It would appear then to be of manifest advantage if the heat could be applied directly to the gas without the intervention of furnace or boiler. The idea was so obvious that it could not fail to attract the attention of those who were trying to overcome the too apparent loss in the steam engine, accordingly numerous attempts were made to obtain an elastic agent by setting fire to a mixture of inflammable gas and air within the very cylinder in which the piston of an engine is working. The heat developed in the gas during the burning would thus supply a source of energy in the closest contact with the moving parts to which the energy is to be transferred. This will furnish a definition of the internal combustion engine.

Comparison may be made to a gun, the cylinder being the barrel; the piston, the bullet; the gas mixture, the powder. However in the gas engine we require instead of an explosion (1) that the pressure shall not rise too suddenly; (2) that the intensity shall be kept within reasonable limits.

About 1860-1870 several forms of gas engines were built, the Lenoir engine (1860), having a great many of the features

*Read before Mechanical and Electrical Section of Society.

of engines of the present time. This engine was not developed, however, owing to the fact that patents were granted for the Otto Atmospheric engine which operated somewhat as described by the comparison to a gun.

The piston was driven free up a long cylinder by the explosion of the gas and at the top of the cylinder the piston rod, which had a rack on one side engaged with a gear to produce rotary motion on the down-stroke under atmospheric pressure.

Following this came the Otto gas engine, this engine being the one which has so firmly established the gas engine on its present commercial basis. The new Otto engine acted on what is known commonly as the four-stroke cycle.

The cycle of operations requires four strokes of the piston or two complete revolutions. Suppose the piston at the head of the cylinder and moving forward. As it moves outward a vacuum is created in the cylinder which draws in the mixture of gas and air through the suction valve, from the mixing valve or carburetor. The suction continues till the end of the stroke when the suction valve closes on the in-stroke of the piston the gas is compressed into the space between the piston and cylinder head called the compression chamuer. This compressing of the gas renders it more explosive and at or just before the end of the stroke the gas is ignited, expansion of the gas occurs and the piston is forced outward, thus transmitting energy to the crank-shaft. When the piston is nearly at the end of its stroke a valve called the exhaust valve is opened mechanically by means of a device called a cam, and on the in-stroke of the piston the burnt gases are expelled from the cylinder head called the compression chamber. This compress- and another intake stroke occurs.

There are thus four operations (1) intake, (2) compression, (3) expansion, (4) exhaust, and since only one of these transmits energy to the crankshaft—the other three withdrawing a certain amount—the need for heavy flywheels on the gas engine is very apparent.

The ignition of the charge is accomplished by two methods chiefly:

(*a*) The hot tube system.
(*b*) Electric spark.

(*a*) A tube of metal or porcelain is inserted into the compression chamber and brought to a cherry-red by means of a Bunsen burner. This tube will ignite the compressed gas at starting and the succeeding explosions will keep the tube hot. The disadvantage this method has is that the only way of advancing or retarding the "time" of ignition is by changing the compression pressure. This system has been very largely displaced by the second method except in the case of oil engines. Two systems are employed: (1) The jump-spark, using a high tension current which will arc across a gap left between two points placed inside the cylinder—the common spark-plug being

the example so well known. This system is used on automobiles and marine engines. (2) The make and break system, using an induced current of fairly low voltage but high amperage which produces an "arc" or spark between two points in the circuit when they are sharply separated. This is the system in use on large engines only instead of using batteries and coil a small dynamos or magneto is used and the "igniters" either mechanically or magnetically operated.

The heat generated by the explosion in the cylinder often reaching 2700 ° renders a cooling system necessary. For this reason the cylinders are cast with a water-jacket; that is, the walls are cast hollow, leaving a space through which water is pumped. In the last few years since double-acting engines have been built it has been found necessary to cast the piston rods and pistons hollow and cool them also by a separate water system. Attempts have been made at air-cooling by casting radiating flanges on the cylinder and having a fan revolving at a high rate of speed to furnish a current of cool air. There are some engines of this type in use but the air-cooled engine is not a very marked success and would probably fail altogether in large units.

Along the same line it has been found necessary to use only a mineral oil having a high flash test, otherwise the oil is decomposed or burned away, leaving carbon deposits on the walls of the cylinder causing pre-ignition owing to the particles becoming red-hot. In extreme cases where the oil is burned away the piston will sometimes "freeze" to the cylinder ruining either or both and perhaps wrecking the engine.

Gas engine governors are of two types:

(1) Hit and miss governor.
(2) Throttle governor.

The first is used on the smaller units. It gets its name from the fact that it automatically regulates the number of ex-explosions, each explosion being equal. The governor used by Fairbanks-Morse is a flywheel governor. When the speed of the engine increases above the limit a collar on the crankshaft is drawn outward along the shaft by the centrifugal action of the weights to which the collar is attached by two bell-crank levers. Drawing out the collar forces a ground steel lever called a "Detent" (one end of which fits in a groove in the collar, and pivoted at the centre) into a notch or a slot on the cam or layshaft rod, thus holding the exhaust valve open hence preventing any vacuum in the cylinder and also the indrawing of the mixture.

Thus the engine runs free and misses a number of explosions until its speed having dropped back to normal the weights swing in, withdrawing the detent from its slot and allowing the exhaust valve to close. A better method is to allow the valves to work as usual but to have the governor lift a

block out of line with the suction valve so that it does not open as its appointed time.

The second type is the throttle governor. Here the governor regulates (throttles) the quantity of mixture taken into the cylinder, each explosion stroke being utilized. When the speed limit is passed the balls in drawing outward draw up a small bell-crank lever to which is attached a rod to operate the butterfly valves in the gas passages. The opening of the throttle valve thus regulates the amount of mixture. This governor has been made so sensitive that it has placed the gas engine in a position to successfully compete with the steam engine in electrical work where very close regulation is necessary to secure a steady light. This governor will give as close as two per cent. maximum variation and better.

For electrical work very heavy flywheels are used while for belt and pump drives lighter wheels suffice. The weight per h. p. of flywheel runs between 500 and 590 pounds for electrical work while in marine and automobile engines this weight will run below 25 lbs. The contrast is very great but it is well known that the latter are very short-lived even with intermittent service.

Simple Poppet valves, usually of forged steel with 45° bevelled seats are used on all gas engines of the four cycle type at least. The inlet valves are either mechanically or automatically operated. The first method is in use on all larger units. The valve is operated by a cam acting on a push-rod and rocker arm, sometimes, however, the push-rod is omitted and the cam acts directly on the rocker-arm (roller contact being provided always). The valves are nearly always mounted in cages independent of the cylinder, thus permitting of quick removal for inspection and regrinding.

Valves are in common practice made about 45-50 per cent. of the cylinder diameter. On large engines the stems are provided with rings to prevent loss of compression and to keep oil from leaking down on the working edges, causing carbonization and leaky valves.

Owing to the high pressures in the cylinder it has been the aim of several manufacturers to provide "balanced" valves. The Riverside Engine Co. have about the best example of balanced valves I could find. The valve used by them is of the poppet type only the head of the valve is left uniform in diameter for some distance up the stem. This extension runs in a liner with rings as mentioned before. Thus the only pressure which can act to hold the value on its seat is that of the helical spring and the weight of the valve. Contrary to usual practice, the valve is "pulled" open, tension springs being used. The valve gear is very simple, the lay-shaft is located on the top of the cylinders, the drive being furnished by short cross-shafts and steel gears (running in oil) from the main shaft. Cams are keyed to the lay-shaft and these cams engage with rollers on the ends

of rocker-arms to raise the valves. The only force necessary to raise the valves is that required to overcome the resistance of the helical closing springs and the weight of the valves.

On engines using liquid fuels the carbureter or mixing valve consists of a small reservoir filled either by a pump or by a gravity system. The former is preferable, the overflow, if any, simply running back to the fuel tank through an overflow pipe, thus maintaining a constant level in the reservoir. The fuel is taken into the cylinder through a needle-valve along with sufficient air through the inlet valve to form a mixture suitable to conditions.

The gas-mixing valve is manually adjusted by means of valves located in the supply passages except in such cases as require variations of the mixture proportions at the same time with variation in the quantity of mixture admitted. For such conditions the lever which raises and lowers the mixture-valve is also linked to butterfly-valves in the passages, the linkage being so arranged that as the load decreases the mixture is made richer and as the load increases is made weaker and the pressure raised. The use of the butterfly-valve helps to make the governor more sensitive since it is a type of balanced valve and its ease of operation is unaffected by the pressure of the incoming gases.

On the gas engine as well as the steam engine the indicator is of the greatest use. On the gas engine, however, a very much stiffer spring must be used. In comparing steam and gas engine diagrams it will be noticed that there is very little difference in height, yet if we remember that the spring used for the steam engine was an 80-lb. spring while that for the gas engine was 160-200 lbs., we can readily see that the initial pressure in a gas engine cylinder is very much higher than that of the steam engine—also the release is at very much higher pressure. Owing to the high frictional losses in the gas engine the indicator is not as accurate as might be for measuring the horse-power but for the demonstration of the best mixture, valve setting, and "timing," of the explosion it is of the greatest use.

The use of gas engines on a large scale has been governed by the field open to this style of prime mover; that is, fields where the steam turbine and Corliss engine are not of practical utility. Two of these, the utilization of natural gas and blast furnace gas, are quite familiar to power users, but of course both are limited. Of late years, however, "producer" gas has been coming to the front. Producer gas can be generated from fuels which cannot be used economically under boilers—some of these fuels—lignite, for example, yielding only about 8,000 B.T.U.'s as fired under a boiler, but in the gas producer and engine it is possible to develop a brake horse-power on less than two pounds of the coal.

The gas producer affords practically the only means of using this coal since it is so difficult to secure proper combustion

under boilers. The same thing is true of slack coal, bone coal and peat.

Underlying 20-30 million acres of public lands in the West are beds of lignite—heretofore supposed useless. The possible industrial development of the West by the producer gas plant is therefore almost unlimited. Gas producers are of two types, suction and pressure producers, the former having the widest use on this continent I will refer to it chiefly.

Producer gas is generated by passing air together with steam at atmospheric pressure through a bed of burning coal contained in a large generator or retort lined with fire-brick. The mixture of air and steam being sucked in by the action of the engine piston.

Leaving the generator the gas, which has a high temperature, is passed through the vaporizer, a cylinder filled with tubes —kept full of warmed water from the cylinder jacket—where it parts with enough of its heat to generate steam in sufficient quantities to supply the producer.

Next the gas passes through a scrubber where it is further cooled and partially cleaned from impurities which would cause trouble in the engine cylinder. The scrubber contains layers of coke over which water is sprayed, removing the dust and cooling the gas by contact with the water.

The next step is the purifier; the gas has to pass through layers of sawdust or shavings which remove the tarry products. From the purifier the gas either goes to a gas tank or direct to the engine, usually the latter.

One advantage which the pressure producer has over the suction producer is that it can use almost any kind of fuel while the suction producer is limited to anthracite, coke and charcoal.

A comparison of gas and steam plants will show that the principal differences are not in the labor, attendance and repairing costs but rather in coal and water consumption per horse-power hour in first costs and life. The gas power plant is without question of very much higher efficiency than that of steam plant and the efficiency of small gas engines is about as high as that of large ones while small steam engines make a very poor showing indeed. Hence we have a clue as to the field where the gas engine is bound to displace the steam plant to a very great extent.

The cost of operation of the gas plant is low compared to that of the steam plant but this saving is offset partly by the increased fixed charge due to the higher first cost of the gas plant made necessary by its massive, rigid construction and the necessity for more and more accurately made parts than the steam engine requires. Also the gas engine is supposed to be shorter lived than the steam engine.

In the largest units steam is so economical that gas plants of equal size suffer in comparison of power costs except of course in the neighborhood of blast furnaces or coke ovens or when

coal is high in price. The gas plant also suffers when the load factor is low; that is, where the possible output is greater than the real output. This offset partly by the stand-by losses of the steam plant which tends to equalize the excess of the first cost of the gas plant.

In view of the above, in isolated gas plants it is advisable to use smaller units and when the load factor is low shut down a part of them. Thus the highest efficiency of those in use is maintained and the losses due to part load eliminated. Under such circumstances the producer gas plant can easily work at about twice the efficiency of the steam plant.

As an example, a 250 h.p. twin gas engine using coal at $2.00 per ton and at 50 per cent. load factor will develop a brake horse-power per hour on .37 cents. This cost is about equal to that of a steam plant of 50,000 h.p. of the best type and is almost absolutely unheard of in engines of a smaller size, hence it will be found that the gas plant is superior since it is capable of producing power at a total cost varying from one-half to one-fifth as much as a steam plant of equal size.

A further development of the gas engine is the gas turbine.

Experiments have been made with a small turbine of the De Laval type capable of developing about 30 h.p. and after noting its performance with compressed air, arrangements were made for using it with a combustion chamber, delivering the products of combustion of liquid hydrocarbon fuel (gasoline) at a constant pressure through a nozzle upon the blades of the turbine. The combustion chamber was lined with a refractory material and tubes were placed in the shell to provide for a water-cooling system. The temperatures reached about 3200° F. and the lining found most suitable was a carborundum shell with asbestos backing inside a metal shell. The nozzles also being of carborundum.

The water after circulating through the jacket tubes is sent through small holes into the combustion gases just before they enter the nozzles, the water being converted into steam which acts to lower the temperature of the issuing gases, preventing destruction of the blades and also by its own expansion helping to drive the turbine.

It has been found necessary that the compressed air for feeding the combustion chamber should be placed from some form of rotary air compressor so arranged that it can be direct-connected to the turbine itself.

This means that the gas turbine must include a rotary air compressor and that such a compressor must have a high efficiency otherwise it will detract very much from the efficiency of the compound machine.

In one large unit the compressor had an efficiency of 70 per cent., but it absorbed about half the power developed by the turbine. The machine running at 4,000 R.P.M. developed 300 h.p. more than that which was absorbed by the compressor.

The thermal efficiency was not as high, however, as that of the reciprocating gas engine but seeing that several 120 h.p. gas turbines have actually been installed for service in the past year and the length of time it has required to bring the reciprocating engine to its present state of perfection there seems to be a very good reason for encouragement of and interest in this form of gas engine.

THE ENGINEER AND THE FINISHED WORK.*

Technical education is a subject receiving much attention in all progressive countries to-day. Germany has set the pace. She has shown what science and skilled workmen can accomplish. Her representatives are met throughout the world, gathering scientific information regarding raw materials, regarding systems of manufacture, regarding details of workmanship, in order that these may be available in "the Fatherland" in producing an improved quality of goods at a decreased cost. This is one of the great secrets of Germany's extending commerce—technical education. England has grasped this fact, and with the foresight and business instinct, characteristic of the British people, we may confidently affirm that its usefulness will be tested to the full extent. Canada, in spite of the many demands upon our resources, is making progress in this regard, and government and educational bodies are making substantial progress in the matter of manual training and the higher technical education.

This is a subject in which the engineer is keenly interested from a direct and personal standpoint. The result of his own education of the labor, skill and care that he puts into his plans and specifications, are dependent upon the grade of workmanship available in securing ultimate results. His own skill and foresight are not sufficient, good material is not sufficient, if these are to be utilized wholly in a rough and haphazard way by untrained workmen and inferior inspectors.

The situation is one which every engineer in Canada must have at times keenly appreciated, when he has looked upon the defective work presumably carried out in conformity with his plans and specifications. Much of the engineering works carried on in Canada to-day, is intentionally designed in an inferior manner simply because of the fact that we cannot depend upon the workmanship that is to be put into them.

The designing engineer cannot himself be always on the ground to give the necessary directions which even skilled artisans require, and between the engineer and the artisan lies the office of the inspector. The training of the engineer is necessarily made up of what we may roughly term "the practical" and "the theoretical." Both are essential. With the engineer on the one hand, the theoretical should predominate. With the inspec-

*From an address delivered to the Toronto Engineering Alumni, on Thursday, Feb. 10, 1910.

A. W. Campbell

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tor; the practical is necessarily the most essential feature. The inspector has need of both the theoretical and the practical if he is to properly interpret the engineer's intention and at the same time apply them in such a way that the contractor can accept in full his directions.

Contractors, however honest, are chiefly concerned in the profits accruing; not the perfection and durability of the work. The contractor's foreman is chiefly concerned in getting the maximum amount of labor for the minimum wage. His efforts are, of necessity, directed toward that phase of the work. It may be accepted as an axiom that the quality of the work cannot be wholly left to the contractor.

There is a great need in Canada to-day for skilled inspectors who will act as the connecting link between the designing engineer and the contractor. The inspector is not simply a watch-dog on the work. He is there to fill a place which the contractor is not, cannot, be expected to fill. I would not separate wholly the work of the inspector from the profession of the engineer. I know of no better training for a young engineer than that experience, when, call him what you will, inspector, resident engineer, assistant-engineer, he has the opportunity of remaining on the ground and studying all the details of practical workmanship. There is need, however, that young engineers prepare themselves for the inspector's duties in a proper manner, by a period of, let us say, apprenticeship.

Theory alone will not make a good inspector. As I have pointed out, the predominating qualification of an inspector should be the practical. He should know the different grades and qualities of material. He should know the different grades and qualities of workmanship. He should know how much work a man or men do in a day, and he should know as far as possible all those details of machinery and methods of doing work which tend to good and bad results.

This information is necessary to him as inspector, but doubly essential, it seems to me, for him to have a full grasp of, when, more closely following the duties of a professional civil engineer, his work will consist of the preparation of plans and specifications, in which he will be controlled and guided by the limitations imposed upon him by the grade of workmanship, material and cost that are the tools with which he must ultimately get results. In Canada to-day we have splendid institutions of scientific education connected with our universities. We establish technical and manual training for artisans, but I would commend to you a more difficult school perhaps, but one in which the rewards are exceedingly satisfactory and gratifying, and which are absolutely essential to the highest grade of engineer. In this school he could start at the lowest rung and work his way up, as he has done in the School of practical Science. The school to which I refer is the school of Experience, in which, as with

all other human endeavors, the way is hard and difficult in proportion to the goal to be attained.

Technical men are not always available, so that we are compelled frequently to employ men of more or less practical experience, but without the theoretical training. Too often we find that these are men who do not value the work of the engineer or architect. To the laymen, the architect or engineer is apt to be a man of fanciful ideas, who can write long specifications, and draw more or less intricate pictures, but who has no ideas of how the work is to be carried out. The untrained man, lacking the basic information as to why the specifications require certain results, is wholly unable to determine how it should be done, if he has not actually seen it performed in his past experience. In concrete, for instance, he has no conception of why the stone and sand should be clean, why they should be mixed in certain set proportions, why the mixing should be thorough. He blunders and stumbles along, hoping the results will be satisfactory, but can give no positive assurance that they will be.

It is the unexpected that happens. No plans or specifications can be so prepared as to meet all emergencies. When something not contemplated by the plans and specifications occurs, the layman's training is seldom equal to the occasion. His opinion of engineers and architects very frequently causes him to find a solution of his own. Lacking the knowledge as to why a thing should be done, he is incapable of determining how the emergency should be faced. When the engineer goes on the ground, it is too often to look with horror on the blunder ing work that has been carried out.

In making these statements, I am reminded that it is difficult to generalize. There are some competent laymen inspectors. But they are men who have grown up on practical work, who are shrewd observers, and have a native capacity that carries them beyond the ability of the average man. Inspectors of this class are rare, however, as they are usually employed as contractors' foremen, or graduates to the ranks of the contractor.

Towns and cities, all municipalities, are frequent offenders in the matter of inspection. Much municipal work has no inspection whatever. Inspectors, when employed, are apt to be local men with a little influence, who have been failures in their own line of work or business. They have great respect for the opinion of the contractor who is doing the work, and very little for the engineer who merely designed it. The inferior results and failures throughout the province in municipal improvements are the unfortunate verification of this situation. When failure occurs, the public look to the engineer as the responsible official, and the reputation of engineering profession has suffered much in consequence.

These are some of the difficulties which we have to face in

carrying on public work. The situation is possibly one which can never be wholly overcome, but we are looking to the technical schools and colleges to supply us with men who will have the necessary practical and theoretical training, and we are at the same time educating public opinion as to the necessity of spending more upon the expert supervision of these works. The public are slow to grasp the value of expert services, and it is only with costly experience through mistakes and blunders of untrained inspectors, that these matters will ultimately adjust themselves.

I am not speaking in the interest of technically trained men but beinug a public official charged with the handling of public funds in connection with public works, I have reached these conciusions from years of experience, and deem it but right that I should give the public the benefit of this experience, and warn them in the interest of good workmanship and economy. Sentiment has been, and to a large extent, still is in opposition to skilled inspection, and where we apparently have so much difficulty in raising monev for doing these necessary works, it seems difficult to understand why we should persistently refuse to adopt the methods that will secure the most successful results.

The inspector requires technical training, combined with experience, to interpret not so much the letter, as the spirit of the plans and specifications. The inexperienced technical student is, on the one hand, apt to be too particular over unimportant details; but the lay man is careless and pliable in the hands of a determined contractor. A couple of seasons in a minor capacity, with two or three years' technical study is a training such as will enable an ambitious young man to become a thoroughly efficient inspector.

The Department of Public Works has frequent occasion to employ inspectors on works under contract. During the past season Mr. Arthur Sedgwick, a graduate of the School of Practical Science, was resident engineer or inspector in charge of regulating dams at the outlet of Dog Lake, the head waters of the Kaministiquia River. These dams were in three sections, of concrete with considerable rip-rap, and when completed it will be possible to develop 40,000 h.p. within a mile of the lake.

A work at Dryden on the Wabigoon River comprising a steel bridge of 80 feet span, concrete abutments 13½ feet high, and a filling 160 feet in length, rip-rapped, was supervised for the Department of Public Works by W. H. Manning of the School of Practical Science. Mr. J. W. Hackner, a graduate, supervised steel and concrete bridges at Nairn, Severn, Vermillion River. The Vermillion Bridge is in two steel spans of 150 feet each, with concrete sub-structure and a 300-feet timber trestle. The Nairn Bridge is of steel 200 feet long, on concrete abutments; and the Severn work was a concrete arch of 58½ feet span, built by Messrs. Gagne and Jennings. Mr. Geo. Hogarth

of the School of Science, was inspector for the Tunnel Bridge on the Missassaga River north of Thessalon, a steel arch of 93 feet span, with a 60-feet steel trestle approach on concrete foundations. Mr. F. W. Robertson, of the School of Science, has made laboratory tests of cement for a number of works.

Obituary

We regret to report the death of C. G. Milne, '92, late Chief Engineer of the Hamilton Bridge Works Co. Mr. Milne was one of the "School's" most brilliant and successful graduates. The profession, the university and the country suffer a distinct loss in his decease.

We have just received word of the death of Wm. Elwell, '02, who died on Sept. 3rd, 1909.

W. E. Cole, '08, one of the most promising men of the class of '08, died at his home at Lucasville on Dec. 31st, 1909.

We regret to report the untimely death of L. A. McLean, '08, on Feb. 14th, in Ottawa, Ont.

According to our custom, full obituary notices of these fellow-graduates will appear in the April issue.

APPLIED SCIENCE

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Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

Published monthly during the College year by the University of Toronto Engineering Society

Editorial

University Extension

The speech of Mr. James P. Murray at the Annual Dinner of the Engineering Society, expressing, as it no doubt does, the views of many of those most deeply interested in the industries of our province, and which is printed in full in this issue of Applied Science, is deserving of more than a passing thought by the students, the graduates and the authorities of this University.

When the representative of the Canadian Manufacturers' Association says, "These thoughts bear on but one phase of a subject which has many sides, any one of which might well deserve a very careful study by our Universities," it is surely time for us to get busy and see what we can do for the development of our Province in the industrial line.

The subject of technical education, which at the present

time is everywhere before the public, the educationist and the statesman, is a very comprehensive one, concerning as it does the schoolboy as well as the workman and mechanic. While Mr. Murray has spoken on only one phase of it, he has touched upon a number of vital points, and during his discussion has answered reasonably a number of the most difficult questions as, for example: Where should the Province look for teachers in this great work? To the students, graduates and staff of the Faculties of Applied Science in our Universities. Who should supply the necessary funds? The State.

What the State has done for agriculture and the farmer in the matter of education, it should do for the industries and the mechanic, certainly sounds fair.

No doubt, the future of this province depends largely upon the future success of her industries, and it is admitted by all that the future of the industries depends largely upon education. It is thus of mutual interest to the State, the industries and the Universities that this matter should be dealt with immediately with the greatest care.

Mr. Murray has presented a feasible plan, which, if at fault, errs in being too modest, and, consequently, not as efficient as it should be. However, with a Royal Commission to be issued so soon, it is perhaps better not to enter into a discussion of details at present. His remarks, however, offer a very strong argument in favor of this, the largest Faculty of Applied Science in the Dominion, situated in the midst of one of our largest manufacturing centres, being represented on the Commission. If the teachers for this great work are to be drawn largely from the graduates of Applied Science, surely the Commission to investigate what is to be done and how it should be done, should number among its members a representative of the University of Toronto.

The New Laboratories

The opening of the new Thermodynamic and Hydraulic Laboratories of the University on January 20th marked a new epoch in the Faculty of Engineering. Unfortunately it was found impossible to make the opening ceremonies as prominent and far-reaching as was originally intended

The members of the Engineers' Club of Toronto were, however, present to hear a lecture by Prof. Angus on Turbine Pumps. The room was crowded to the doors. After the lecture the buildings were thrown open for inspection. All the machinery and equipment was in full operation.

The visiting engineers were loud in their praises of the building and the equipment, which is fully described in this.

It is planned to hold more of these practical meetings during the course of the year, interesting and acquainting as many interests as possible in the workings of the University.

THE ENGINEERING SOCIETY.

The month of January has been a very busy one for the Engineering Society. The dinner, of course, was the most important event of the month. All the meetings were well attended. The sectional meetings held up to the usual high quality of addresses.

Dean Galbraith addressed the Civil and Architectural Society on "The History and Failure of the Quebec Bridge."

N. S. Sherman spoke on the "Gas Engine before the Electrical and Mechanical Section." The paper is published in full in this issue of Applied Science.

W. P. Cohoe addressed the Chemists and Mines on technical Training of Industrial Chemists.

The general meeting of the Society was of especial interest. H. F. Ballantyne, '93, of New York, spoke on "Architecture."

The address was listened to with great interest and profit by the students. Mr. Ballantyne deserves greatest credit for coming from New York on purpose to address the Society.

A special general meeting was held in Convocation Hall on Jan. 20th. The meeting was addressed by Mr. Knight, inventor of the Knight Automobile Engine. The history, importance use of the engine was most interestingly and convincingly demonstrated.

WHAT THE GRADUATES ARE DOING.

This section is conducted with a double object in view—First, to give the graduates professional news of each other; secondly, to give the undergraduates an idea of the possible fields of employment open to them in the future.

F. R. Beatty is assistant to manager of the ornamental iron department, of the Canada Foundry, Toronto.

C. A. Topp has resigned the position of City Engineer for Vancouver.

A. R. Raymer, '84, is assistant chief engineer of Pittsburg and Lake Erie Railroad Co.

W. J. Chalmers, '89, with United States Engineers' Office on construction and maintenance of locks and dams and general river and harbor work, with headquarters at Pittsburg, Pa.

J. W. Goodwin, '92, is superintendent of construction contracts 64 and 66, New York State Barge Canal, for Empire Engineering Corporation, New York.

J. Keele, '93, the Geological Survey, Ottawa, at present employed on investigation of clays in both field and laboratory work.

W. J. Herald, '94, is with the Canada Foundry Co., Toronto, on blast furnace and general design.

A. T. Gray, '97, is in turbine engine department, General Electric Co., Schenectady, N.Y.

L. B. Chubbuck, '99, is engineer-in-charge of switchboard and detail design, Canadian Westinghouse Co., Hamilton.

R. W. Coulthard, '99, is general manager of Western Canadian Colleries Limited, Blairmore, Alta.

John A. Bain, '00, is structural engineer, with Dept. Public Works, Ottawa.

E. T. J. Brandon, '01, is with Hydro Electric Power Commission, Toronto; assistant engineer engaged on design and on irrigation works at Kelowna, B.C.

Chas. Harvey, '01, civil and consulting engineer, specializing construction of transformer stations for high tension transmission system.

F. Y. Harcourt, '02, engineer Public Works Dept., in charge of dredging and building breakwater at Port Arthur, Ont.

D. M. Johnston, '02, is superintending engineer with Jones & Moore, Toronto.

D. L. H. Forbes, '02, metallurgical engineer in charge of design and construction of Concentrating and Cyaniding Mill for Lucky Tiger Combination Gold Mining Co., Yzabal, Senora, Mexico.

H. G. Barber, '02, is in Topographical Surveys Dept., Dept. of the Interior, Ottawa.

A. L. McLennan, '02, has finished his contract on the Gow Ganda wagon road. It speaks for his ability when he made good on a proposition that was given up by several other parties.

A. C. Goodwin, '02, is an inspector with the Dominion Wire Manufacturing Co. at Montreal.

H. H. Angus, '03, is with the Bethlehem Steel Co., at Bethlehem, Pa.

F. F. Clark, '03, is a divisional engineer on construction, with Canadian Northern Ontario Railroad.

H. E. Job, '04, is a manufacturer of electrical machinery and aparatus, Spring St., Hamilton.

A. Gray, '04, is superintendent of St. Lawrence Starch Co., Port Credit, Ont.

J. W. Goodall, '04, is superintendent of construction on Hydro Electric Power line, Ontario Government.

M. M. Currie, '04, is chief inspector and engineer, with the Hamilton Steel and Iron Co., Limited, Hamilton, Ont.

Ried Munro, '04, has returned from a two berth experience on the Hudson Bay Survey, and has joined the staff of Smith, Kerry & Chace at the Toronto office.

Murray Hendry, '05, is in the Toronto office of C. H. Mitchell, C. E.

R. H. Armour, '05, is sales engineer with Westinghouse Electric Mfg. Co., 165 Broadway, New York.

C. B. Aylesworth, '05, is in draughting department of the Canadian Westinghouse Co., Hamilton.

W. A. Begg, '05, is prospecting and developing mining property with headquarters at Haileybury, Ont.

S. R. A. Clement, '05, is with the Hydro Electric Power Comm., Toronto.

T. E. Corrigan, '05, is chief electrician for Standard Consolidated Mining Co., at Bodie, Cal.

N. L. Crosby, '05, is designer on structural steel, with the McClintic, Marshall Construction Co., Pittsburg, Pa.

W. G. Hewson, '05, electrical engineer on installation of 11,000 h.p. hydro electric plant at Cobalt, Ont.

G. Kribs, '05, engineer-in-charge of electrical design, Smith, Kerry & Chace, Toronto.

W. Hoover, '06, Crown Reserve Mine, Cobalt, Ont.

A. Cameron, '06, draughtsman, detailing on structural steel for Canada Foundry Co., Toronto.

A. W. Campbell, '06, is inspector on transmission lines for Hydro Electric Power Comm., Toronto.

R. E. Chadwick, '06, has been appointed bridge engineer, in charge of bridges and docks for the City of Toronto.

H. D. Bowman, '07, Ontario Power Co., Niagara Falls, Ont., employed on drafting in connection with the extension of plant.

O. B. Bourne, '07, is field draughtsman, in charge of field draughting on City of Winnipeg Hydro Electric Construction, Winnipeg.

F. G. Allen, '07, is assistant foreman of testing department, Burke Electric Co., Erie, Pa.

F. Alport, '07, is resident engineer of the National Transcontinental Railway, Wako, Ont.

A. D. Le Pan, '07, has been appointed Assistant Superintendent of the University of Toronto.

J. A. Stiles, '07, has resigned from the staff of the University to accept the position of resident engineer on the extension the Port Credit Brick Co.'s works, for Haney & Miller.

C. T. Hamilton, '07, is in charge of field party on the alignment for tunnel section of penstocks No. 2 and No. 3 for Ontario Power Co. plant at Niagara Falls, Ont.

E. W. Hyman, '07, is assistant superintendent London Electric Co., London, Ont.

Walter Jackson, '07, with Ontario Power Co., Niagara Falls, Ont.

C. B. Jackson, '07, engineer in charge of estimating department, the Everett Clora Co., general contractors and builders, Chicago, Ill.

D. F. Keith, '07, electrical engineer, in charge of Hydro Electric Power Plant, of the Telluride Power Co., Provo, Utah.

E. W. Kay, '08, is in sales department Canadian Westinghouse Co., Hamilton.

S. B. Iler, '08, is with Canadian General Electric Co., Peterborough.

E. G. Hewson, '08, assistant to resident engineer, G.T.R., Toronto.

F. L. Haviland, '08, is with the Hamilton Bridge Works Co., at Hamilton, Ontario.

C. Van Norman, F. E. H. Mowbray and C. F. Publow, all '08 men, are all at the Canadian Westinghouse Co.'s works, Hamilton.

H. T. Bowes, '08, is superintendent of Warren Bituminous Paving Co., with headquarters at Toronto.

J. H. Bruce, '08, is with the New York Telephone Co., in the plant and equipment department, New York.

E. J. Brown, '08, is with the Canadian Westinghouse Co; assistant engineer on construction, Nipissing Power Co., Nipissing, Ont.

W. F. M. Bryce, '08, is in the City Engineer's Dept., Ottawa, Ont.

P. H. Buchan, '08, in the estimating and draughting department, British Columbia Electric Ry. Co., Vancouver, B.C.

D. Cameron, '08, is employed in the Maintenance of Way Dept., Canadian Pacific Ry., Toronto.

N. A. Campbell, '08, is chief chemist Canada Cement Co., Calgary, Alta.

H. R. Carscallen, '08, is assistant hydrographer under P. M. Sauder, for Dept. of Interior, Calgary, Alta.

Geo. Challen, '08, is superintendent of the American Road Machine Co. of Canada, Goderich, Ont.

A. D. Dahl, '08, is general analytical chemist, with the John Taylor Soap Co., Toronto.

John Darroch, '08, is draughtsman with Autoparts Mfg. Co., Detroit, Mich.

C. Douglas, '08, is field engineer for the Standard Sanitary Mfg. Co., on construction of their new plant in Toronto.

A. M. Bitzer, '09, is with Western Electric Co., Chicago, Ill.

E. G. Arens, '09, is in charge of machine department of E. Long Mfg. Co., at Orillia, Ont.

H. V. Armstrong, '09, is assistant engineer, with Willis Chipman, Toronto.

E. T. Austin, '09, is with the G. M. Guffey Petroleum Co., Beaumont, Texas, in charge of the construction and maintenance of pipe lines.

C. G. Cline, '09, is foreman on construction, Hydro Electric Power Plant, at Stave Falls, Ruskin, B.C.

R. H. Douglas, '09, structural engineer, Dept. of Public Works., Edmonton, Alta.

Jas. E. Gray, '09, draughtsman, Canadian Bridge Co., Walkerville, Ont.

J. W. Hackner, '09, is employed as inspector on construction of steel and concrete bridges, with Provincial Dept. of Public Works.

Geo. Hogarth, '09, draughtsman and engineer on highway bridges, Dept. of Public Works, Toronto.

THESES.

The following list completes the subjects for theses for degree B.A.Sc. handed in by the men of the Civil Electrical and Mechanical Departments. The mining and chemical men have had their time extended:—

Brown, E. W.—"Materials of Track"—Discussion on construction of railroad track.

Cameron, M. G.—"Bacterial Disposal of Sewage"—Septic tanks, contact beds, and percolating filters.

Collinson, J. G.—"Concrete"—Plain and reinforced.

Graham, D.—"Purification of Water"—Dealing with the most recent developments in this line.

Hunter, A. E.—Concrete—The manufacture of plain concrete.

Johnston, J. T.—"Concrete Lock Construction"—With special application to locks on Trent Canal.

Kemp, J. B. O.—Street Lighting by Electricity—The plant, equipment, and field of various systems; the possibilities of the Tungsten lamp.

Key, W. R.—Compressed Air—Theory and practice.

Lamont, A. W.—Single Phase Series Commutation Type Motors Its development, improvements and operation.

Lennox, A. D.—Lightning Phenomena and Protective Apparatus in Electric Circuits—Causes and effects of dangerous rises in voltage on transmission lines and some of the commoner devices for protection against same.

Langmuir, B.—Four Cycle Single Acting Producer Gas Engines —Conditions governing practical operation and design.

MacArthur, A. S.—Tunneling—General construction as applied to railroad work.

Mamson, A. B.—Highways—The construction and maintenance of highways.

Munro, F. V.—Plate Girder Bridges Construction—The theory of design and types of construction.

McPherson, M. W.—Dams—General description of construction of dams.

Morton, G.—Single Phase Series Motor—General advantage of alternating current; defects, evolution, and methods of improving; the single phase motor, adaptability to railroad work, including control and characteristics.

MacMillan, V.—Tunneling—A comparison of different methods, with special attention to rock work.

McCuaig, P. J.—Shaft Governors—Evolution, theory, modern types.

Manning, N. H.—Steam Turbines—Discussion of types; advantages of low pressure turbines and steam turbine reciprocating engines; efficiency of various types.

Newton, J.—Irrigation—A description of the construction and application of various systems of design.

O'Hearn, J. J.—Insulation—Various materials employed and methods of testing.

Porter, C.—Switch Boards and their Equipment—A synopsis of the design and equipment of the modern switchboard.

Redfern, C. R.—Sewage Disposal—Treating with modern methods adaptable to Canadian conditions.

Richardson, F. L.—Railway Tunnels—Methods of excavation, track laying in tunnels, ventilation, lining and waterproofing; description of various tunnels.

Ricker, H. A.—Producer Gas as Generated by Pressure Producer Plants—Analysis of gas, general description of plants and units comprising them.

Rutlidge, L. T.—Modern Electric Train Control—Description of various types of control of street cars and electric trains; the necessary apparatus for series—parallel control, multiple unit control, A. C. control and the various brake systems in use.

Schwenger, C. E.—Multispeed in Polyphase Induction Motors—Description of various methods of producing multispeed and operating characteristics of them; practical application.

Stroud, S.—The Alternating Current Series Motor—Operation, control and characteristics of the motor; methods of overcoming operating difficulties.

Saunderson, A. W.—Irrigation—History, duty of water, equipment of systems, and application.

Swan, R.—Waterpower Development.

Tait, H. W.—Culverts—Construction of Railway and Highway culverts with cost data.

Taylor, W. E.—Physical Properties of Concrete—Plain and Reinforced—A synopsis of the conclusions of the most authorative experimentors on the properties of concrete which a designer should know.

Taylor, J. W. R.—Maintenance of an Electric Power System from the Standpoint of the Operating Company—Power house, transmission line, transformer, distribution system.

Thompson, E. A.—Variable Speed Alternating Current Motors—The characteristics of the various types of motors proposed for tractive purposes and operated by alternating current.

Tipper, G. A.—Street Pavements—Construction of various types.

Toms, C. G.—Welding of Iron and Steel—Describes various methods of welding from hand-forging to later methods.

Trees, A. G.—Gas Engines—Development and construction of both two and four cycle types.

Vatcher, A.—Piles and Pile Driving.

Walker, J. A.—Aerial Tramways—Their importance, construction and operation as applied to mining.

Webb, C.—Signalling—Block systems as used in United States and Great Britain; mechanical interlocking as used at grade crossings in Canada.

West, A. M.—Public Water Supply.

Williamson, O. T. G.—Irrigation—The general layout of an irrigation system with a discussion on the types of weirs.

Wilkinson, R. G.—Drainage of Farm Lands.

Topical Song from the Menu Card

We are honored with professors that deserve a barrel of toasts;
Let us hope they don't consider it to be a barrel of roasts,
For we love them all so dearly just at this time of the year,
That we would indeed regret it if we saw one shed a tear.

What a prince at mathematics is our mystic Louis B.,
For when he gets near a blackboard only white things can we see;
And with Peter G. Dynamics,—Oh! Now wouldn't it be fun
To have Stewart and Gillespie run a mutual marathon.

Here's to 'Fessor Grandie Anderson, the man who makes the Heat,
And a splash of Hydrostatics, just enough to wet your feet.
In an hour or two of lectures we're supposed to learn to swim,
But alas! at the exam. we find our bathing suits are thin.

Let us toast the freshies' father and the guardian of us all,
Who compare our brilliant future with the stresses on a ball,
When there's games or meets a plenty or events just like to-night,
There is not a loyal helper than can beat Professor Wright.

Then there's our Professor Angus who has got a right to crow
At his monumental chimney and his Thermo. lab. below.
We would like to ask a question if he thinks we're not too bold—
Should it not have trousers on it to protect it from the cold?

Here's to our Professor Rosebrugh with his theory fresh from Mars,
Though his stock of blackboard drawings must have wandered thro' the wars.
Very often he may hear us murmur softly, "What's the use";
But apart from what he tells us, he's a man that knows the juice.

Here's to one that's new amongst us, O. U. H. O. T. Haultain;
New Professor and new benedict we're glad he's here again.
He has been out in the open and he learned a lot of things.
We can't say that he's an angel for he hasn't got the wings.

Our Professor John McGowan is a man who deals in "strength,"
Tho' he can't compare with Samson for his hair is shy of length;
But our John says, "There's a reason, as we all can plainly see,
Since old Samson never lectured in a university."

Just a word to Dr. Ellis, right hand factor of the Dean,
Though his pastime is a mystery and he is seldom seen.
When the season's strife is over and his lectures are all through,
Will he analyze the contents of the work we didn't do?

Here's to one we've near forgotten, not because he is so small,
But because he knows his lessons and is high above us all;
And if we be quiet and careful we can always pin our faith
To the Pillar of the Faculty, our worthy Dean Galbraith.

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